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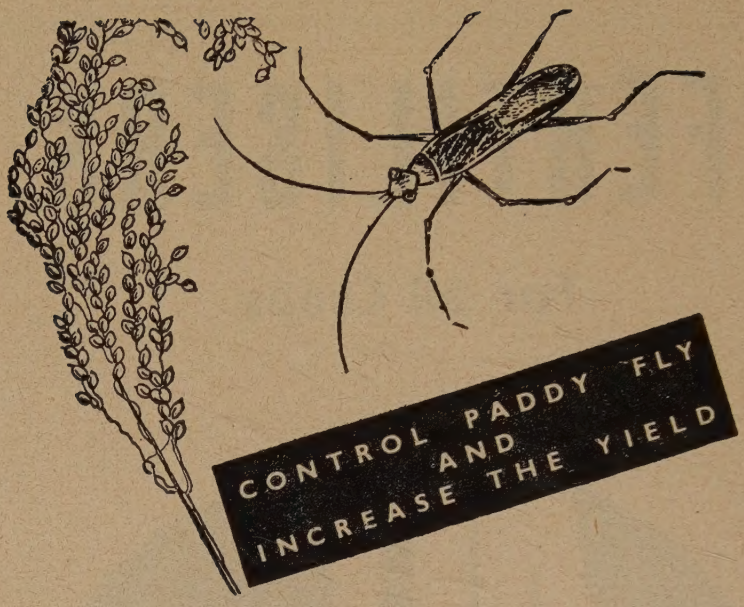

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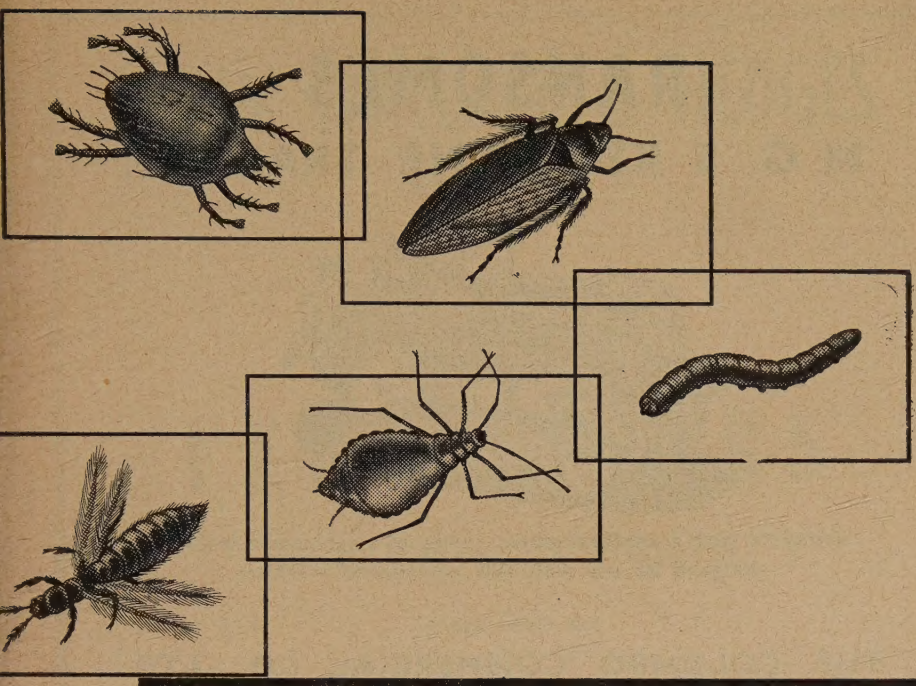

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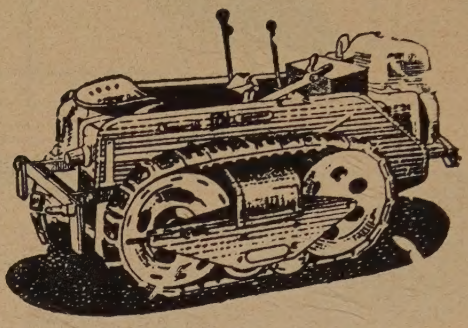

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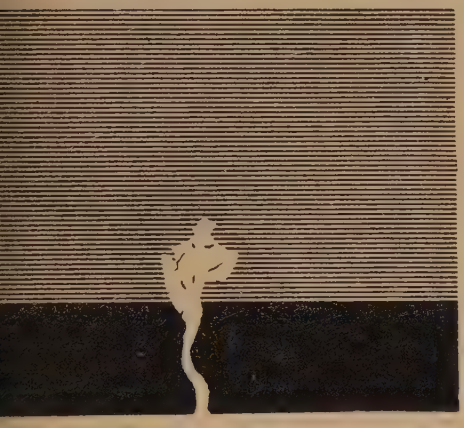

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AGRICULTURAL JOURNAL OF CEYLON

VOLUME CXV, NUMBER 3, 1959

Edited by

DR. M. F. CHANDRARATNA
Director of Agriculture

CEYLON DEPARTMENT OF AGRICULTURE

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EDITORIAL

Variety—Fertilizer Interactions in Rice

THE *japonica* × *indica* hybridisation project sponsored by the International Rice Commission assumed the existence of a higher fertilizer response in the *japonica* forms commonly grown in Japan, and attempted combining this character with the greater adaptation to a tropical environment that *indicas* possess. It was, however, realised that although continuous selection for low fertility levels may have considerably depleted fertilizer response in the *indica* forms indigenous to the tropics, the search within these *indicas* for reserves of fertilizer response that have survived selection may prove profitable. Since 1951, when the Working Parties on Rice Breeding and on Fertilizers jointly sponsored the co-ordinated "Investigation of Variety-Manuring Interactions with Particular Reference to N and P", member countries of International Rice Commission have conducted an active search for *indica* varieties that manifest marked fertilizer response. Reviewing the results reported from participant countries, one appears justified in claiming that this co-operative investigation has delivered on its promise. Several member countries of the International Rice Commission have detected in their indigenous *indica* varieties, considerable reserves of fertilizer response. The experience of rice breeders in Ceylon, however, suggests that there is much greater promise of success in selection for fertilizer response within the progenies of crosses between *indica* varieties than in straight selection. The exceptional performance of the Batalagoda selection H-4 is illustrative of the potentialities of such hybrid material.

Except in Ceylon, no attempt appears to have been in the experiments in tropical countries to record much more than the gross yield of grain and straw. An analysis of grain output into yield components would be of considerable value in deciding on the choice of cultural methods, and in the selection of parents for hybridisation. A high-response variety of the panicle-number type is suitable for transplanting at a relatively wide spacing. A panicle-weight type should on the other hand be broadcast. Both types of varieties exist among the *indicas*.

It was earlier believed that heavy panicles generally characterize low-response varieties. The hybrid H-4, however, combines heavy panicles with high panicle number. There is evidently no physiological or structural difficulty in achieving this combination.

Heavy nitrogen manuring aggravates both lodging and blast, and it is unlikely that much progress can be made in the breeding of high-response varieties until more information on the physiology and genetics of resistance to lodging and blast becomes available. The need for co-operative investigations in these fields is urgent.

In regard to the quantitative evalution of fertilizer response in rice, investigators have often contented themselves with little more than recording the significance or the reverse of the variety × fertilizer interaction in the variance analysis table. It does not appear possible to effect detailed comparisons of the behaviour of varieties unless a satisfactory response curve is available for each variety under test. There is evident need for including a sufficient large number of fertilizer levels to permit the calculation of a quadratic regression function of the type

$$y = a + bx - cx^2$$

where y is the grain yield that the fertilizer does of x units is expected to provide. All three constants, a, b and c have a significant meaning in the interpretation of fertilizer response. The constant a estimates the basic yield of the variety at the no-fertilizer level. The best estimate of fertilizer response is provided by the differential coefficient :

$$dy/dx = b - 2cx.$$

The constant c indicates the rate at which the response declines. The objective of the rice breeder should be to select for high values of a and b, and for a low value of c.

THE NATURE OF FERTILIZER RESPONSE IN JAPONICA AND INDICA RICE VARIETIES

By

DR. NOBORU YAMADA *

(Chief Research Co-ordinator, Department of Agriculture, Ceylon)

WITH the object of elucidating the different types of fertilizer response in rice varieties, growth and yield components of three Japonica and two Indica varieties were examined under three levels of fertilizer application, during the Yala season of 1959.

MATERIALS AND METHODS

1. Varieties used :

Japonica type :

Norin No. 1, *Taichung* No. 65 and *Kanan* No. 8.

Indica type :

Murungakayan 302 and H-4.

2. Nitrogen levels :

Using 1 ft. square concrete pots, containing 30 Kg of soil each, the treatments shown in Table 1 were given :

Table 1.—Fertilizer Treatments

Fertilizers	*Levels (gm/pot)*			*Time applied*
	Low (N^0)	*Medium* (N^1)	*High* (N^2)	
Ammonium sulphate (Basal dressing)	0	0·5	2·0	11 July
(Top do.)	0	1·0	4·0	18 Aug.
Superphosphate	0	1·0	4·0	11 July
Potassium sulphate	0	0·5	2·0	11 July

On 14th July, seedlings (26 days old) were transplanted in the pots at a spacing of 6 " x 6 " with three seedlings per hill, and four hills per pot.

*Expert from Japan under the Colombo Plan.

RESULTS AND DISCUSSION

1. Yield and yield components in relation to fertilizers

Grain yields and yield components for individual varieties are given in Table 2 and Fig. 1.

All varieties used showed remarkable increase in grain yield as the fertilizer application was increased, with the exception of *Murungakayan* 302. Percentage increase in grain yield of N_2 against N_0 was about 50 per cent. with three Japonica varieties and 70 per cent. with H-4, but no increase was observed with *Murungakayan* 302. The yield increase of *Norin* No. 1 was almost entirely caused by the increase of panicle number per hill. As shown in fig. 2, yield of N_2 is 153 per cent. of that of N_0, and panicle number of N_2 is 148 per cent. of that of N_0, but the weight of individual panicles is not affected by the fertilizer levels, showing only 4 per cent. increase at N_2. Therefore, the yield increase of 53 per cent. of this variety was caused by the increase of panicle number by 48 per cent. and by the increase of panicle weight by 4 per cent. This class of variety in which yield increase is obtained mainly by the increase of panicle number and not by the increase of weight of a panicle is designated " the panicle number type " in Japan.

On the other hand, response of *Kanan* No. 8 was manifested more markedly in the increase of weight of individual panicles than in an increase in panicle numbers (fig. 1 and 2). Yield increase of 44 per cent. resulted from the 25 per cent. increase in panicle weight and 15 per cent. increase in panicle number. Average weight of a panicle is much higher than in Norin No. 1 and increases with the application of fertilizer. This is an example of the so-called " panicle weight type ".

Taichung No. 65 is an " intermediate type " with a response intermediate between *Norin* No. 1 and *Kanan* No. 8.

H-4, the hybrid selection recently produced by Mr. H. Weeraratne, at the Central Rice Breeding Station, Batalagoda, from a cross between M 302 and *Mas*, is shown to be " panicle number type ". The yield at N_2 was 171 per cent. of that N_0 and this yield increase can be accounted for mainly by the increase of panicle number by 59 per cent. and partly by the increase of panicle weight by about 7 per cent. (figs. 1 and 2). It is very interesting that this variety, H-4, is able to produce very heavy panicles in spite of its being essentially a " panicle number type " (fig. 1). Thus, as it combines the characteristics of the "panicle number type " with heavy panicle weight, H-4 can give very high yields under fertilizer application. The performance of this variety might be superior to that of *Norin* 1, one of the leading varieties of Japan.

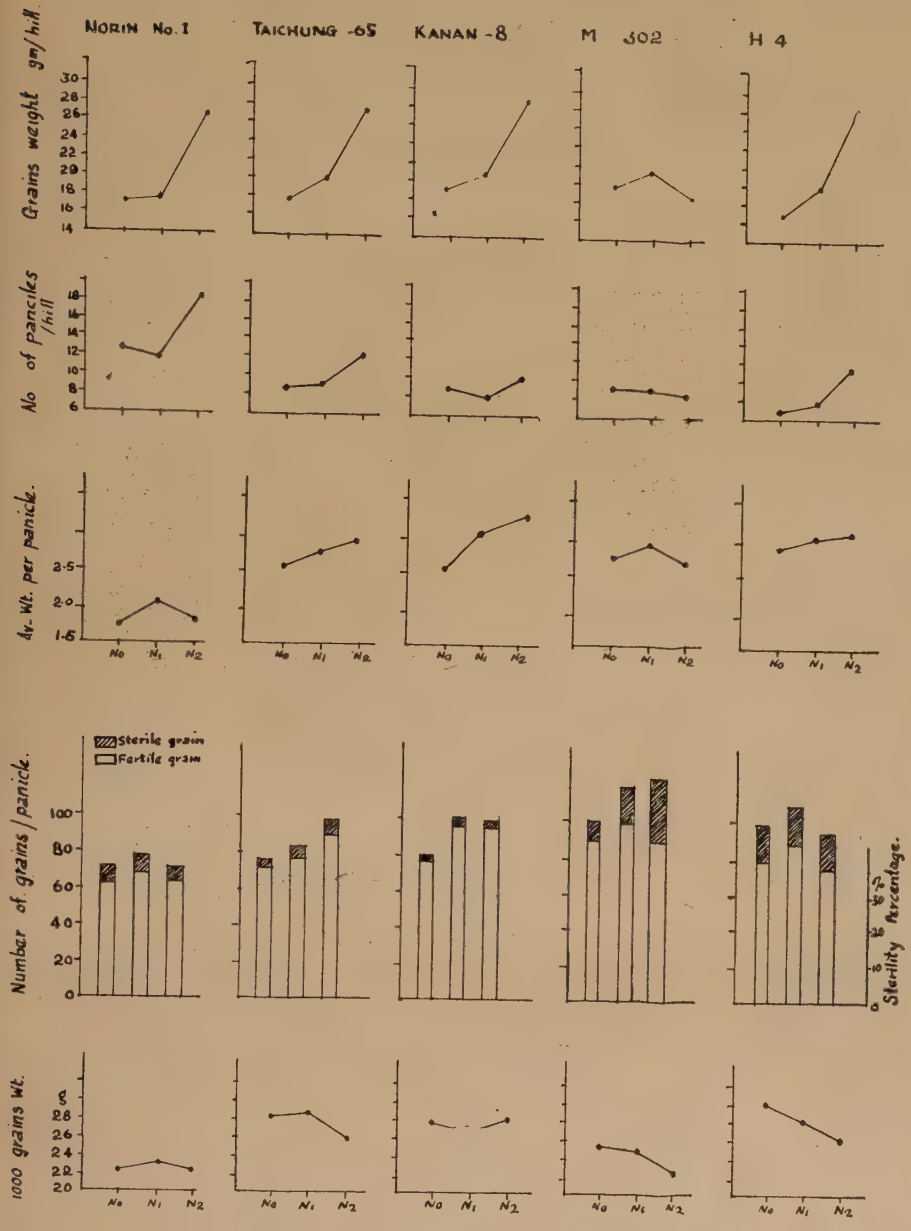

Fig. 1. YIELD AND YIELD COMPONENTS

TABLE 2—YIELD AND YIELD COMPONENTS

Variety	*Fertilizer level*	*Grain Weight g/hill*	*Number of panicles per hill*	*Average Weight of a panicle*	*Number of grains per panicle*	*Percentage of sterility*	*Weight of straw g/hill*	*Grain Weight total top weight %*	*Dry Wt. top roots g/hill*	*Days sowing to harvest*	*Dry Wt. production per day*
Norin—1	N_0	17·5	12·5	1·40 g	69·3	12·7	18·6	48·5	38·4	122	0·314 g
	N_1	17·7	11·0	1·63	76·0	10·9	17·8	49·8	36·6	121	0·302
	N_2	26·8	18·5	1·45	69·5	11·4	23·1	53·7	52·2	123	0·421
Taichung—65	N_0	17·2	8·3	2·06	76·4	5·1	18·6	48·0	38·1	131	0·291
	N_1	19·6	8·5	2·30	85·5	5·7	18·0	52·2	39·3	133	0·296
	N_2	27·5	11·5	2·49	99·8	6·8	27·6	49·9	57·2	132	0·433
Kanan—8	N_0	18·3	8·5	2·16	81·5	3·7	23·4	43·9	44·8	138	0·324
	N_1	19·8	7·8	2·56	103·9	5·3	22·9	46·4	45·0	139	0·324
	N_2	26·4	9·8	2·70	101·1	3·9	35·3	42·8	64·6	140	0·462
Murungakayan—302	N_0	19·7	8·8	2·25	100·0	12·5	33·7	36·9	55·3	147	0·376
	N_1	21·8	8·8	2·49	116·3	15·8	45·4	32·4	70·7	147	0·481
	N_2	18·5	8·5	2·17	120·0	30·0	57·1	24·4	80·2	149	0·538
H–4	N_0	16·5	6·8	2·44	100·2	23·0	27·3	37·7	46·9	145	0·323
	N_1	19·9	7·8	2·56	109·8	21·2	33·4	37·3	55·6	147	0·378
	N_2	28·2	10·8	2·62	95·5	26·1	43·9	39·1	75·6	152	0·498

Contrary to this, *Murungakayan* 302 shows increase in neither panicle number nor in panicle weight and accordingly no increase in yield under fertilizer application. But under N_0 condition (without fertilizer), this variety shows highest yield among all varieties used. So that this variety is characterized by high yield without fertilizer, and no response to the fertilizer. It should, however, be mentioned that the experimental land was extremely fertile and the nutrient status of the soil even at N_0 would have been very high.

As illustrated in fig. 1, with varieties of the panicle weight and intermediate types, the increase of panicle weight caused by fertilizer application is accompanied by increase in grain number per panicle, i.e., the weight of a panicle is raised by increasing grain number per panicle. But, with the panicle-number varieties, such as *Norin* No. 1 and H-4, no increase of either panicle weight nor of grain number per panicle takes place. It is interesting to note that *Murungakayan* 302 behaves like a panicle-weight variety, showing increase in grain number per panicle. But the sterility percentage shows a marked rise and consequently the number of fertile grains is rather reduced in spite of the total increase in grain number per panicle.

In general, sterlity percentage is higher with indica varieties than with Japonica varieties, and *Murungakayan* 302 particularly showed a striking increase in the sterility percentage under fertilizer application.

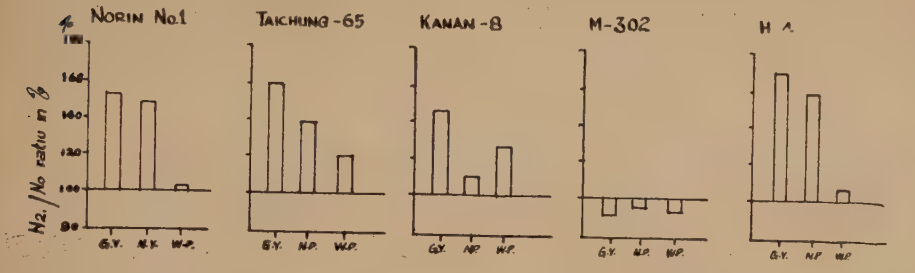

Fig 2 YIELD AND YIELD COMPONENTS AT N_2 AS EXPRESSED AS PERCENTAGES OF NO

G.Y. = Grain Yield
N.P. = Number of panicles per hill.
W.P. = Average weight of a panicle

2. Dry matter production and distribution between grain and straw

The total dry matter of grains and straw per hill at the time of harvest is illustrated in Fig. 3. In general, the Indica varieties are able to produce more dry matter than Japonica varieties. Of course, the

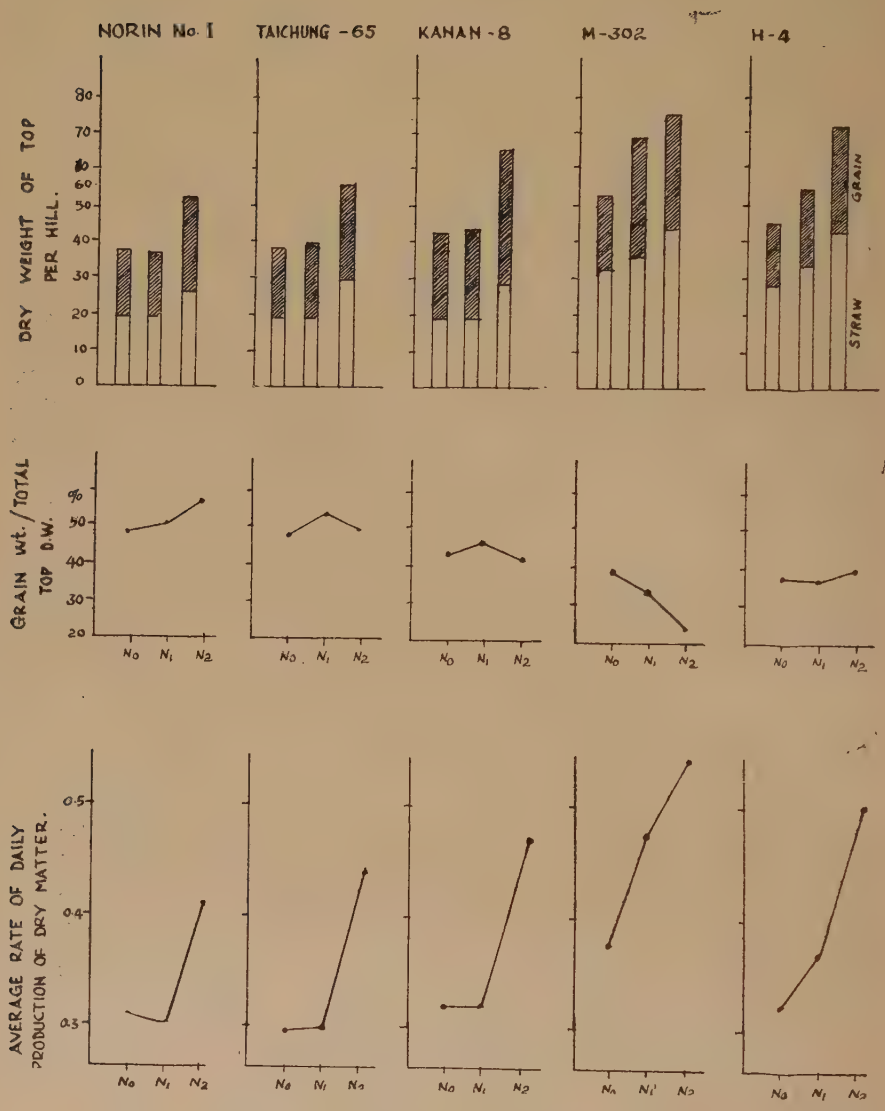

fig.3 DRY MATTER PRODUCTION AND DISTRIBUTION BETWEEN GRAINS AND STRAW.

production of dry matter depends upon the growth duration and the rate of daily photosynthetic production. So that a late variety can accumulate more dry matter than an early variety, even though the daily rate of production of the former may be less than that of the latter. The total dry weight of plant (including dry weight of roots) divided by the number of days from sowing to harvest gives the average daily rate of dry matter production. As shown in Fig. 3, Indica varieties possess a higher daily rate of dry matter production than Japonica varieties. It is evident from these results that the efficiency of dry matter production is higher with Indica varieties than Japonica varieties ; *Murungakayan* 302 particularly has a very high daily rate of dry matter production and the rate rises with fertilizer application.

However, the Japonica varieties are able to utilize about 50 per cent. of the total dry matter in grain production, while Indica varieties can utilize less than 40 per cent. of the total dry matter for the same purpose. Although *Murungakayan* 302 possesses the highest rate of dry matter production, the ratio of dry matter appropriated in grain formation to the total dry matter is the lowest, and the proportion decreases considerably with fertilizer application. At the N_2 level only 25 per cent. of the total dry matter can be used in grain production, and 75 per cent. is diverted to straw.

From the physiological point of view the distribution of dry matter between grain and straw appears to be determined by varietal differences in nitrogen and carbohydrate metabolism. The low rate of distribution of dry matter to grain is possibly due to the following physiological causes :—

(1) Nitrogen absorption is possibly high, in nitrogen assimilation a large quantity of the photosynthetic product, glucose, is consumed.

(2) Moreover glucose is utilized to produce cell-wall substances, such as cellulose, hemicellulose, &c.

(3) The result is the vigorous growth of vegetative organs, and the depressed accumulation of starch before heading as well as the low production of starch after heading.

In short, the problem lies in the chemical components of the dry matter ; starch production and accumulation in relation to nitrogen level is the most crucial factor in determining dry matter distribution. The problem continues to be actively investigated in my laboratory.

3. Type of fertilizer response

In the present experiment, *Murungakayan* 302 showed no response to fertilizer application. But according to the fertilizer experiments hitherto undertaken at several places, this variety had shown considerable response. The soil used in the present study was very fertile, and this is the reason why this variety did not show fertilizer response. On poor soil, deficient in nutrients, this variety can respond to fertilizer application. Therefore, the difference in the response between this variety and others, including H-4, can be explained as shown in Fig. 4.

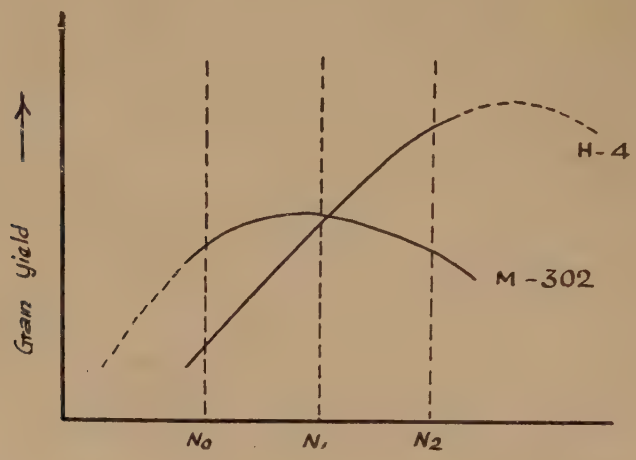

fig: 4. SCHEMA OF RESPONSE OF M-302 AND H-4.

Murungakayan 302 shows very high activity in the absorption of nutrients even from the less fertile soil and accordingly it absorbs too much nitrogen under fertile conditions; absorption of too much nitrogen in relation to starch production results in decreased yield. The failure of this variety to show increase at all in panicle number when fertilizers are applied must be a morphological limiting factor to increasing yield.

The solution culture experiment conducted at Peradeniya, demonstrated very clearly that the concentration of nitrogen recommended as adequate for Japonica varieties and therefore called a standard

concentration* is too high for the Indica varieties, causing striking retardation of root development especially with *Murungakayan* 302. Moreover, even with the reduced concentration of nitrogen, *Murungakayan* 302 showed a strikingly high percentage of sterility and straight head when nitrogen was supplied up to heading time. H-4, however, did not suffer by the supply of nitrogen at this reduced concentration. These results clearly indicate that the optimum concentration of nitrogen is different between Japonica and Indica varieties, and between *Murungakayan* 302 and H-4.

To revert to Fig. 4, the results of the present experiment may be regarded as expressing the relative yield of *Murungakayan* 302 and H-4 at N_0 and N_2 levels in the two response curves.

Finally, it is clear from the results and interpretation presented above, that there are different types of fertilizer response in paddy varieties. Some varieties have a low optimum fertilizer level, and others a high optimum range. With some varieties yield increase is entirely due to the rise in the number of panicles per hill ; with others, increase in weight of individual panicle is mainly responsible for the yield increase. Some other varieties behave as intermediate between these two groups. A knowledge of the characteristics of varieties is essential for the adoption of correct cultural and breeding techniques. For example, it is now evident that *Murungakayan* 302 is not suitable for transplanting and for conditions of very heavy fertilization ; this variety performs satisfactorily when broadcast and when the soil is unfertilized or when the application of fertilizer is not excessive. On the other hand, H-4 can produce high yields under transplanting with wide spacing and heavy applications of fertilizer. Tillering capacity and panicle number assume importance in the breeding of varieties for conditions of transplanting.

SUMMARY

For the purpose of elucidating the different types of fertilizer response in rice varieties, growth and yield components of three Japonica and two Indica varieties were examined at three levels of fertilizer application in pot soil culture during Yala of 1959 at Peradeniya.

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* Standard concentration of N in culture solution is C = 20ppm—N ; during the tillering stage : C, 2C ; from end of tillering period : $\frac{1}{2}$C, $\frac{3}{4}$C ; before and after heading : $\frac{1}{2}$, $\frac{1}{4}$C ; from 2 weeks after heading : 0.

Reduced concentration used was 20 ppm—N during only the active tillering stage, and later the concentration was reduced to less than C, as indicated above.

All varieties, except *Murungakayan* 302, showed striking yield response to fertilizers. The process by which this yield increase was obtained, however, differed with variety. Yield increase in *Norin*-1 was entirely caused by the increased number of panicles per hill (panicle—number type), while *Kanan*—8 showed more marked increase in the weight of the individual panicle than in the number of panicles (panicle—weight type). *Taichung*-65 behaved as an intermediate type.

The response of the Ceylon hybrid H-4 was that characteristic of the panicle—number type. *Murungakayan* 302, on the other hand, belongs to the panicle—weight type : grain number per panicle was increased by fertilizer application. But, because the optimum range of fertilizer levels for this variety is not very high, percentage sterility rose considerably with heavy fertilization and resulted in a reduced weight of panicle.

Indica varieties, as exemplified by *Murungakayan* 302, by reason of their very high daily rate of dry matter production, are capable of producing more dry matter than Japonica varieties, but the distribution of this dry matter to grain is less efficient ; a high sterility percentage and a low ratio of grain to total dry matter result.

Murungakayan 302 is suitable for broadcasting on unfertilized soils or at moderately high fertility levels. H-4, on the other hand, can produce very high yields under transplanting with wide spacing and at high intensities of fertilizer application.

ANALYSIS OF THE YIELD POTENTIAL OF THE INDICA HYBRID, H-4

By

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IN the paper on "The Nature of Fertilizer Response on Japonica and Indica Rice Varieties", the type of fertilizer response manifested by H-4, the hybrid selection produced by Mr. H. Weeraratne, Manager, Central Rice Breeding Station, Batalagoda, from a cross between *Murungakayan* 302 and *Mas,* was subjected to detailed analysis. This communication attempts to examine the yield potential of this hybrid under normal field conditions.

On a paddy field in the Central Research Station at Peradeniya, H-4 was cultivated in the *Yala* season of 1959, under the management of Mr. L. T. P. de Soysa, the Farm Manager of the Station. The growth and yield of the paddy plants were examined in detail. As explained below, plants grown in a part of the field showed very clear evidence that a yield higher than 160 bushels per acre is possible with this variety under the present cultural techniques of this country, although the average yield of the whole field was 120 bushels per acre. This growth and yield were not obtained in experimental or small-scale pot culture, but in actual paddy fields with normal cultivation methods.

1. Condition of the field and cultural practices

The paddy field is 11,000 square feet (approximately quarter acre) in extent as shown in fig 1. Portion A of the field showed poor plant growth due to severe rush of water which frequently occurred after heavy rain, while in portion C plant growth was somewhat better than that in portion B. The observation was made on the portion B where plant growth was intermediate between A and C.

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The whole extent of the field has a very deep soil layer of about two feet for the development of the root system of plants, with the exception of the area C, where the soil is more or less sandy. Irrigation water is available from a spring but the water supply is sometimes inadequate.

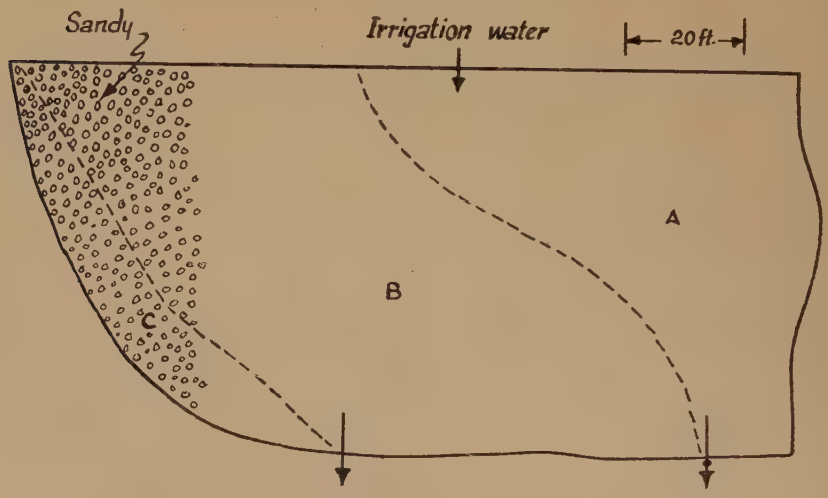

fig: 1.

MAP OF PADDY FIELD

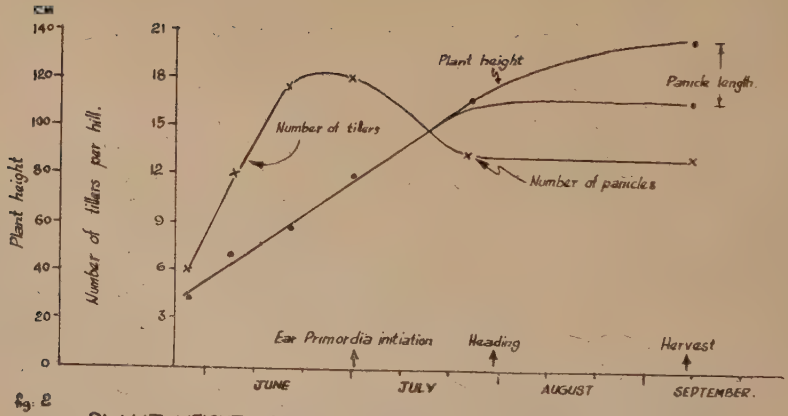

fig: 2

PLANT HEIGHT AND NUMBER OF TILLERS PER HILL

The variety H-4 was sown in a nursery bed on 10 April. On May 2, seedlings (22 days old) were transplanted in the field at a spacing of 10 in. × 6 in. with three seedlings per hill. Fertilizers applied were as follows :—

Basal dressing :	
Sulphate of ammonia	50 lb. per acre
Conc. superphosphate	67 lb. per acre
Muriate of potassium	50 lb. per acre
Top dressing :	
Sulphate of ammonia	100 lb. per acre.

Basal dressing was made just before the second ploughing, and top dressing of nitrogen was made on July 1 (about 30 days before heading time). Two weedings were done with the rotary weeder. No severe incidence of diseases and insect pests was observed.

2. Growth of the plants

Growth of the plants as expressed by plant height and number of tillers per hill is shown in Fig. 2. Number of tillers per hill increased up to approximately 18 by the end of June. Final number of panicles per hill was 12.8, as shown in Table 1. Therefore the percentage of fruitful tillers to the total (maximum) number of tillers was about 70 per cent. This percentage value is as high as that usually observed with Japonica varieties of same growing duration in Japan (1) indicating that tillering was not excessive in proportion to the nutritional supply during the later growing period, even though the tillers were as many as 18, and that there was no shortage of nutrients causing lowering of percentage of fruitful tillers in proportion to the magnitude of early growth. In other words, the growth during the early period and the later period of vegetative growth stage was fairly well balanced.

At the time of heading, several plants were sampled and starch content of the plants was determined. The basal portions of leaf sheath and stems were found to contain a great deal of stored starch, estimated to be as much as ten per cent. of the total dry weight of these organs. This indicated that the plants were able to accumulate a great deal of starch to be utilized in the development of grains after heading. It is well known that shortage of nitrogen results in small plants with high content of starch, while a high nitrogen level induces big plants but with a low content of starch. (2) In the former case, although starch content is high, total quantity of starch available for grain development is less, and the daily production of starch after

heading too cannot be high because of the small plant size and restricted leaf area. In the latter case, daily production of starch after heading is high because of the large leaf area and high photosynthetic rate due to high nitrogen content of leaf, but the quantity of starch stored for grains before heading is less, and the result is shortage of starch in proportion to the increased number of spikelets (due to high nitrogen content), to which starch is to be delivered. Therefore, in the former case yield cannot be high, and in the latter case numerous empty grains and small grains are produced, which tend to reduce yield. But the H-4 plants which were sampled were large and at the same time they had accumulated a great deal of starch. This is the typical characteristic of high-yielding paddy plants.

3. Harvest crop examination

With ten hills sampled at random from the area B of the field just before harvesting, observations shown in Tables 1 and 2 were made. In Table 1, plant height, number of tillers and panicles per hill, and length of panicle borne on the longest stem are shown. Twenty panicles were then sampled at random from the above ten hills, and measured as shown in Table 2. Sterility percentage by number of grains and by weight was determined as shown in Tables 3 and 4.

According to these results, average values of the yield components are as follows :—

Number of panicles per hill .. 12·8
Number of grains per panicle .. 111·6
Number of grains per hill .. 12·8 × 111·6 = 1428·5
Number of fruitful grains per hill = 1428.5 × 0.784 = 1119.9
Weight of 1,000 grains = 30.2 gm.
Then, weight of total fruitful grains per hill = 33.8 gm.

Average grain yield per hill, 33.8 gm., thus calculated, is slightly less than the value obtained by simply averaging grain yield of ten hills, 36.1 gm.

4. Yield estimation

Taking average grain yield per hill as 33.8 gm., and taking average spacing as 10 x 6 inches, yield per acre is estimated as follows :——

33.8 gm. × 104544 = 3533.6 kg = 7773.9 lb. = 169 bushels.
where, 104544 = number of hills per acre, and bushel weight is taken as 46 lb.

This estimation is based on the minimum value of average grain yield per hill and the minimum number of hills per acre, but still the estimated yield shows more than 160 bushels of paddy per acre.

Unfortunately the cultivation was not done for the purpose of this experiment, so that the growth and yield of paddy are not uniform throughout the field as shown in Fig. 1 and harvesting was not made separately with A, B and C areas. There was also a certain amount of loss due to grain shattering during harvesting and transporting.

The divergence between the estimated yield of 169 bushels per acre for the plot B of the field and the actual harvest of 120 bushels per acre from the whole field can be attributed to these reasons.

The poor growth and yield in area A of the field indicates that the improvement of irrigation and drainage is an important factor in raising the general level of yield.

The total number of hills per unit area is just the same with the spacing of 10 in. × 6 in. and of 12 in. × 5 in. Therefore, it is suggeted that it would be better to adopt the spacing 12 in × 5 in., instead of 10 in × 6 in., order to secure more light and aeration to the plants and also to facilitate field practices such as weeding and spraying, without reducing the number of plants per unit area.

Strictly speaking, this report deals only with the evidence shown by plants themselves of possibility of obtaining 160 bushels of paddy per acre. But, it gives us confidence and encouragement that the yield as high as 160 bushels per acre could be achieved, because it was actually obtained even though in a small area.

It has been believed for long years that paddy is better suited to the sub-tropical and warm temperate zones than to the tropics, and that paddy grown under tropical conditions may possibly not be capable of giving the high returns possible in more temperate climes. (Grist 1959) (3). However, the progress in improving varieties and cultural techniques in this country has achieved a yield as high as that reported here. Even a yield of 120 bushels per acre is the higher class of yield in Japan. The possibility of obtaining a higher yield than this is indicated by the above observations.

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Table 1.—Plant and Panicle

Plant No.	*Plant height*	*No. of tillers*	*No. of Panicle*	*Panicle Length*
	cm			*cm*
1	128·5	15	11	29·0
2	145·0	23	15	31·0
3	133·5	13	12	28·5
4	134·5	19	13	31·0
5	140·5	23	13	28·0
6	135·5	25	19	28·0
7	140·5	18	11	30·0
8	138·5	14	9	30·0
9	135·5	15	14	28·5
10	134·0	13	11	29·5
Mean	136·6	17·8	12·8	29·35

3—J. N. R 8342 (2/60)

Table 2.—Panicle and Grain

Panicle Sample	*Panicle length*	*No. of grains*	*No. of rachis branch*	
			1st order	*2nd order*
	cm.			
1	26·0	101	12	16
2	25·5	117	12	22
3	26·3	133	12	24
4	28·6	176	13	34
5	26·8	140	12	26
6	24·5	126	12	26
7	22·3	59	9	13
8	22·8	76	9	10
9	27·1	119	12	17
10	28·6	163	12	32
11	23·7	93	9	11
12	24·6	120	13	22
13	27·7	160	14	34
14	25·4	128	12	22
15	26·0	112	12	21
16	16·7	30	6	3
17	20·8	95	10	13
18	25·8	98	11	17
19	25·6	139	13	25
20	27·8	147	13	26
Mean	25·13	111·6	11·4	20·7

Table 3.—Sterility and grain weight

Sample No.	*Fruitful grains*	*Empty grains*	*Total number of grains*	*Weight of 1000 grains*
A	156	36	192	30·15
B	168	52	220	28·04
C	179	43	222	31·21
D	140	47	187	31·36
E	294	70	364	30·44
F	189	63	252	30·12
Total or Mean	1,126	311	1,437	30·22

Sterility percentage by number of grains .. $\frac{311}{1437} = 21{\cdot}6\%$

Table 4.—Weight of Straw and grain per ten plants

Weight of straw	578·5 gm
Weight of total panicles	409·7
Weight of total panicles without grains	28·5
Weight of empty grains	19·9
Weight of fruitful grains	361·4
Sterility percentage by weight $= \frac{19{\cdot}9}{381{\cdot}2}$	$= 5{\cdot}2\%$

HIGH YIELDING VARIETIES OF RICE RESISTANT TO BLAST

By

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ATTEMPTS to increase rice yields by fertilisation have been off-set by an incidence of blast, caused by Piricularia oryzæ, in both local and introduced varieties grown in Ceylon. For instance, the Indonesian variety, *Mas,* which gave very high yields with fertilization in Ceylon, is susceptible to blast. The Indonesian varieties, *Bengawan, Remadja, Tjahaja* and *Sigadis* are resistant to blast but do not yield as high as *Mas. Podiwi* a-8, a popular six months variety grown in Ceylon is susceptible to blast, while *Ptb-16* an introduction from India is the only other variety in the same age-class which shows some resistance to this disease. Some local varieties have been found to show resistance to blast, but with the exception of *Murungakayan,* their response to fertilizers has not been impressive. *Vellai Illankalayan* 28061, for instance, is resistant to blast and was the most popular improved variety until fertilizers came into extensive use after the second World War. It benefited little from fertilizers and was replaced by *Murungakayan 302* which was soon the most popular variety in Ceylon, mainly because of its high response to fertilizer and its resistance to blast. Some years later, selection in hybrid progenies of *Murungakayan 302* × *Mas* gave H-4 which is strikingly resistant to blast and is the highest yielding variety yet known in this country. It possesses not only high fertilizer response but a wide range of adaptability. It tillers profusely, and has short straw and thin culms, with moderately long panicles bearing well-filled grains. Unlike *Murungakayan 302,* it is completely awnless and is less susceptible to bronzing. It takes four months from sowing to harvest and being relatively insensitive to day-length can be grown both in the *Maha* and *Yala* seasons in this country. Yields obtained with this variety are compared with those of *Vellai Illankalayan* and *Murungakayan 302* in Table 1.

Table 1.—The performance of H-4 in yield trials in three consecutive seasons

Variety		Yield per acre (bushels)		
		Yala 1958	*Maha 1958/59*	*Yala 1959*
Vellai illankalayan	28061	69	59	68
Murungakayan	302	85	72	85
H-4		107	84	119

H-4 has a milling out-turn of 72 per cent. by weight, and its rice is red in colour.

Two other varieties of hybrid origin bred recently in Ceylon are H-105 and H-501. Both these varieties are highly resistant to blast. H-105 is a cross between C-104 and *Murungakayan* and was bred in the dry zone of Ceylon, while H-501 was selected from progenies of GEB 24 × *Vellai Illankalayan* in the ill-drained soils of the low country wet zone. Like H-4 both varieties have a red rice colour, and take four months from sowing to harvest and are grown in both the *Maha* and *Yala* seasons. H-105 gave yields as high as 100 bushels per acre with fertilization, while H-501 exceeded 50 bushels per acre in a district with an average yield of 20 bushels per acre. H-501 sheds its grain easily, but this is not considered a serious objection, because easy threshing is desired in the district where it is grown. H-501 shows resistance to bronzing.

The resistance to blast of varieties presently recommended in Ceylon as determined by Pieris and Marks (1959) is shown in Table 2.

Table 2.—Degree of resistance of improved varieties recommended by the Department of Agriculture

Pachchaiperumal	2462/11	SS
Vellaiperunel	28724	SS
H—105		RR
Murungakayan	302	R
Murungakayan	104	RR
H—4		RR
H—501		R
Hondarawala	502	S
Pokkali		MS
Sigadis		RR

Periavellai	538	..	R
Devaredderi	26081	..	SS
Ptb—16		..	M
Podiwi a—8		..	SS

RR — Very highly resistant
R — Highly resistant
MR — Very resistant
M — Moderately resistant
MS — Moderately susceptible
S — Fairly sucseptible
SS — Very susceptible

All the recommended varieties recently bred in Ceylon, except *Hondarawala* 502, are resistant to blast, while varieties that have been under issue for fifteen years or more, with the exception of *Periavellai* 538 are susceptible.

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THE PROGRESSIVE REDUCTION IN THE NUMBER OF RICE VARIETIES UNDER ISSUE IN CEYLON

By

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THE existence of large numbers of cultivated varieties of a crop in any country indicates not only a low level of crop improvement but also the prevalence of primitive cultivation standards. When, for instance, a crop is traditionally grown without the application of fertilizers, as often happens with rice in many areas in South-East Asia, conscious or natural selection eventually leads to the establishment of ecotypes which manifest equilibrium with the soils and climates of the region: in each season of cultivation, as much nutrients are removed by the crop as are replaced by natural processes of weathering and by microbiological activity. Such an ecotype is claimed to possess a high degree of adaptation to the region.

If the adapted ecotype, which is necessarily a low fertilizer response form, is replaced under unfertilized conditions by a high-yielding strain, more nutrients are removed from the soil than are replaced by natural chemical and biological processes, and after a few seasons of cultivation, yields decline, i.e., the high-yielding strain exhibits symptoms of starvation.

If the above analysis of the phenomenon of local specialisation of rice varieties is correct, it should be possible to reduce the number of varieties in general cultivation by the adoption of high levels of fertilizer application. In Ceylon, the successful breeding of high fertilizer response varieties and the promotion of fertilizer use have resulted in a striking reduction in the number of selections under issue to growers. Moreover, it has been the experience of breeders in this country that if fertilizer applications are adequate, high-response

selections manifest a wider range of suitability than low-response forms. It is also true that there is strikingly greater promise of successful selection of such high-response forms within hybrid progenies than by straight selection in indigenous varieties.

A report on Paddy Statistics published by the Department of Census and Statistics in 1956, records two hundred and sixty varieties of rice as grown in Ceylon. Of these 44 have a sowing-to-harvest duration of six months, 45 of five months, 73 of four months and 44 of three months. The distribution of the varieties in the 3, 4, 5 and 6 month age groups in each of the Districts is shown in Table 1. Generally, varieties grown in the *Yala* (South-West Monsoon) season have a shorter duration than those grown in the *Maha* (North-East Monsoon) season, and this is particularly so in the Dry Zone of Ceylon, where an inadequate supply of irrigation water restricts cultivation to varieties of three months duration. With an assured supply of water, four months varieties are generally grown in both seasons, or a long term variety is grown in the *Maha* season with a short-term in *Yala*. In some districts with a high rainfall in *Yala*, the possibility of floods limits cultivation to a single long-duration crop, sown or transplanted in July-August and harvested in January and February.

The multiplicity of varieties grown in Ceylon was ascribed to a high degree of local specialization. When these varieties were tested their performance was generally disappointing, their yields were low, and their genetic variability did not permit much advance on selection. Selections made in the more promising varieties were compared with standard pure lines and introduced varieties. The only outstanding local variety was *Murungakayan*, a selection of which, *Murungakayan* 302, out-yielded all other varieties in about half the Island's acreage in the dry zone of Ceylon, and also in some parts of the wet zone. Of several hundred introduced varieties, only a few, such as Ptb-16, Mas and Sigadis were found promising.

As a result of extensive yield trials forty improved varieties in all were recommended for the Island. More recently, the hybrid selection H-4 derived from a cross between *Murungakayan* 302 and *Mas* out-yielded *Murungakayan* 302 and other improved varieties,

wherever they were compared in Ceylon. The list of Departmental recommendations has now been reduced to 14 varieties which are as follows :—

Varieties	*Age in months*
1. Pachchaiperumal 2462/11	3
2. Vellaiperumal 28724	3½
3. H—105	4
4. Murungakayan 302	4
5. Murungakayan 104	4
6. H—4	4
7. H—501	4
8. Hondarawala 502 (Maha only)	4
9. Pokkali	4
10. Sigadis	4½
11. Periavellai 538 (Maha only)	5
12. Devaredderi 26081 (Yala only)	5
13. Ptb-16 (Maha only)	5½
14. Podiwi a-8 (Maha only)	6

While H-4 satisfies the demand for a variety in the 4 months age class we have so far not been successful in obtaining a three months variety to replace Pachchaiperumal 2462/11, which though extensively grown in *Yala* in the dry zone of Ceylon, is susceptible to blast and is subject to shedding. In the six months age class, Podiwi a-8 is popular because of its small white grain, but its yield is not sufficiently high, especially when it is affected by blast. Ptb-16 is moderately resistant to blast, but it does not meet the demand for a palatable small-grained white rice. Material in the breeding plots appears to fulfil this demand, and a small, white-grained rice may soon be available in both the five and six months age classes.

While both local and introduced varieties are of limited use in this country, there is every possibility that recommended varieties in the future would be few, covering more extensive areas than hitherto imagined. There seems little doubt that in Ceylon these varieties must necessarily be of hybrid origin.

ACKNOWLEDGMENT

I am greatly indebted to Dr. M. F. Chandraratne for his help in the preparation of this paper.

Table I.—Distribution of local rice varieties of various age classes in the districts of Ceylon

District	*Season*	*Number of Varieties in each age-class* 3 months	4 months	5 months	6 months	*Total*
Jaffna	Maha	5	10	14	6	35
	Yala	4	—	—	—	4
Vavuniya	Maha	—	17	3	4	24
	Yala	6	—	—	—	6
Mannar	Maha	3	6	2	—	11
	Yala	4	—	—	—	4
Anuradhapura	Maha	—	16	2	—	18
	Yala	13	—	—	—	13
Puttalam-Chilaw	Maha	3	6	1	14	24
	Yala	6	3	4	—	13
Trincomalee	Maha	—	5	3	2	10
	Yala	5	2	—	—	7
Batticaloa	Maha	5	21	4	2	32
	Yala	18	1	—	—	19
Hambantota	Maha	12	2	2	3	19
	Yala	11	2	—	1	14
Polonnaruwa	Maha	—	2	2	—	4
	Yala	2	—	—	—	2
Kurunegala	Maha	7	12	8	23	50
	Yala	15	7	1	—	23
Badulla	Maha	8	15	15	2	40
	Yala	14	12	3	—	29
Nuwara-Eliya	Maha	4	7	11	5	27
	Yala	6	6	3	—	15
Ratnapura	Maha	1	2	1	2	6
	Yala	1	2	2	2	7
Matale	Maha	1	3	2	1	7
	Yala	3	2	1	1	7
Kandy	Maha	1	4	4	19	28
	Yala	9	7	5	—	21
Kegalla	Maha	—	1	2	18	21
	Yala	5	11	3	—	19
Colombo	Maha	5	16	8	28	57
	Yala	4	15	15	6	40
Kalutara	Maha	12	16	3	5	36
	Yala	3	7	25	—	35
Galle	Maha	10	1	3	—	14
	Yala	8	3	9	2	22
Matara	Maha	4	6	4	1	15
	Yala	7	10	4	—	21

WATER CONSUMPTION PATTERN OF CROPS IN THE DRY ZONE ENVIRONMENT*

By

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INTRODUCTION

A STRIKING feature of rainfed, arable crops in the dry zone environment has been the enormous variability in yield between years. In his early investigations which extended over several seasons, Abeyratne (1) clearly demonstrated the existence of optimum sowing dates within the season in respect of the presently cultivated upland crops. An adoption of these optimum sowing dates has nearly eliminated the yield variability within the season ; but the absurdly high variation in yield between seasons has neither been reduced nor evened out by any agronomic technique.

Cotton reflects the nature of this variation better than most other crops which suffer seriously from bird damage in some years. Over the last eight years (excluding *maha* 57-58) cotton yields at the Dry Zone Research Station, Maha Illuppallama, have varied from 220 lb. to 1,118 lb. seed cotton per acre as shown in Table 1. No differences even remotely approaching this order have been recorded in any of the cotton fertilizer trials conducted through the same span of years. It is therefore clear that factors other than soil fertility which contribute to this enormous variation deserve closer identification and study.

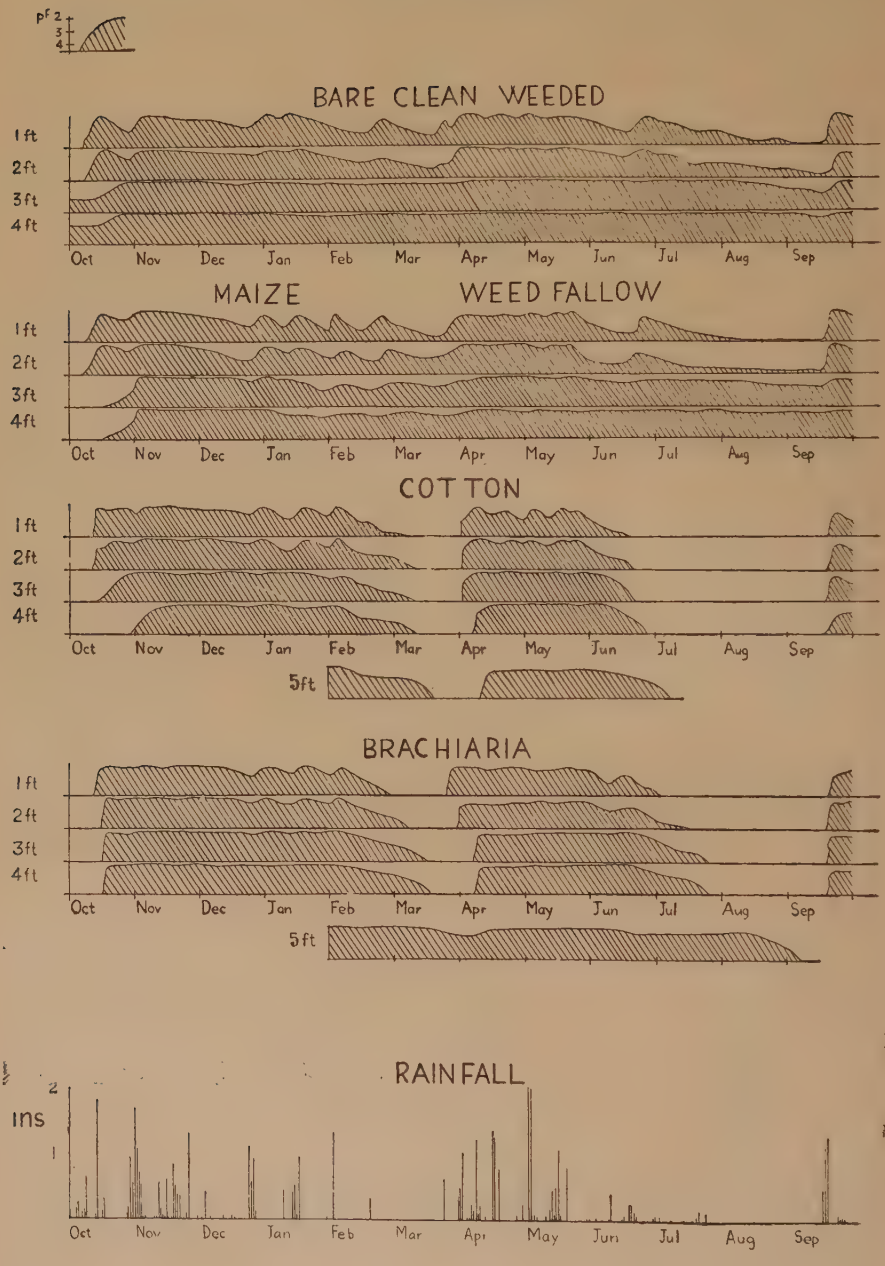
TABLE I.—Yields of seed cotton lb/acre

Season	*Yield*	*Rainfall (Season) in.*	*No. of wet days*
Maha 50/51	1,092	23·19	57
„ 51/52	690	33·72	38
„ 52/53	492	15·00	30
„ 53/54	306	40·58	52
„ 54/55	353	40·60	42
„ 55/56	220	18·50	27
„ 56/57	1,118	20·11	44
†„ 58/59	885	25·20	43

† The 58/59 yield refers to the variety H. C. 101. All other seasons refer to the variety B.P. 79.

* Contribution No. 9 from the Division of Dry Zone Research.

FIGURE 1


pF 2
3
4
BARE CLEAN WEEDED
1ft
2ft
3ft
4ft
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
MAIZE
WEED FALLOW
1ft
2ft
3ft
4ft
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
COTTON
1ft
2ft
3ft
4ft
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
5ft
BRACHIARIA
1ft
2ft
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4ft
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
5ft
RAINFALL
ins
2
1
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Table 1 reveals the remarkable influence of seasonal rainfall on cotton yields. From past experience, it is observed that crop performance in this environment is chiefly governed by the rainfall and the soil moisture sequences which result through the season. Prior to estimating how these components interact to express crop yield, a knowledge of the water consumption pattern of the crop is essential.

Rainfall estimates for crops that are commonly quoted in agricultural literature suffer from a major defect in that no allowance is made for differences in evapotranspiration under different environmental conditions. Another aspect which is often overlooked is that of the moisture reserves in the profile which are residual from the preceeding season.

This paper discusses the results obtained from a field measurement of the water consumption of crops which take into account the foregoing considerations. A future publication will discuss the bearing of these findings on the rainfall characteristics of this region.

CLIMATE, SOILS AND CROPPING SEASONS

The main climatic features of the dry zone have been sufficiently described by Abeyratne (2); soil temperatures and meteorological data were given in a previous publication (3), while more complete data is given in Table 2.

TABLE 2.—Meteorological data for the Research Station

Month	*Mean Rainfall 50 yrs.* (*in.*)	*Mean Evaporation Sunken tank 5 yrs.* (*in.*)	*Mean Max. Temp.* °*F.*	*Mean Min. Temp.* °*F.*	*Mean rel. Humidity* %	*Mean daily sunshine* *hrs.*
January	5·5	5·27	83·3	69·1	81	7·23
February	1·9	5·60	87·0	69·4	74	8·64
March	4·6	7·12	91·2	71·6	73	8·59
April	7·2	7·20	91·6	74·4	76	8·82
May	4·2	7·75	90·8	76·4	76	9.04
June	1·3	7·80	90·0	76·4	71	7·68
July	1·5	7·75	90·8	75·9	70	7·28
August	1·6	8·35	91·4	75·5	68	8·36
September	3·0	8·40	91·8	75·0	68	8·54
October	9·4	5·90	89·0	73·5	77	5·99
November	10·0	4·50	85·8	71·4	81	6·39
December	8·0	4·02	83·2	70·1	83	5·48
Total	58·2	79·66	—	—	—	—
Mean	—	—	88·8	73·2	74·8	7·67

This experiment was located on the ' Emai ' soil series of the Research Station, which is the most widespread catenary member of this region (4); this corresponds to profiles A and B described by Panabokke (3). Total soil depth is 5 to 6 ft. and the quartz gravel horizon is nearly absent at this site.

The main growing season—*Maha*—commences with the first effective rains which fall any time between late September and early October. Annual crops sown with these rains are harvested during February to March with the exception of cotton (variety H.C. 101) and dhal (*Cajanus cajan*) which extend into June. The shorter *Yala* season commences with the late March to early April rains and the crop is harvested by late June to early July.

EXPERIMENTAL PROCEDURE

Commencing October, 1957, the following cropping systems were studied :—

1. Bare clean weeded soil.
2. Continuous grass cover (*Brachiaria brizantha*).
3. Continuous legume cover (*Alysicarpus vaginalis*).
4. *Maha* cotton extended into *Yala.*
5. *Maha* dhal extended into *Yala.*
6. *Maha* maize—*Yala* weed fallow.
7. *Maha* sorghum—*Yala* sunhemp (*Crotolaria*).
8. *Maha* groundnut—*Yala* gingelly (*Sesamum*).
9. *Maha* Kurakkan (*Eleusine*)—*Yala* cowpea.
10. Continuous (*Dolichos lab-lab*) cover.

Plot size was 20 ft. by 10 ft. with two replicates of each cropping system; standard crop spacings recommended for this region by Abeyratne (1) were used in these plots.

Soil moisture changes in the centre of each plot were measured in situ down to the 4 ft. depth and also to the 5 ft. depth in some instances by electrical resistance gypsum blocks (F.F.F. type). All electrical leads were mounted on an upright wooden stake which was driven into the ground. The lower limit of the sensitive range of these blocks corresponds to a pF of 2.5. The moisture change between pF 2 and pF 2.5 for the 0-3 ft. depth was measured with a tensiometer (Gallenkamp), while for depths below 3 ft. the less sensitive change in the resistance of the gypsum block between pF 2 and 2.5 was employed.

Initially, direct soil sampling for gravimetric estimation of soil moisture was carried out in adjacent plots. Thereafter, the soil moisture content was estimated by combined use of the pF—water content curve for each horizon, and the pF—resistance curve for the gypsum block. Field capacity moisture content was defined at pF 2, and free drainage assumed at tensions wetter than pF 2. It was further assumed that there was no uptake of water by the plant when the soil was drier than a tension of pF 4.2.

The bulk density of each horizon was determined on undisturbed core samples and the water content was finally expressed in inches of water per foot depth of profile. The clay mineral being predominantly kaolinite, the calculations were made as for a non-swelling soil.

Parallel observations on precipitation and run-off were kept throughout the course of this investigation in addition to the daily observations on the environmental factors which contribute to water loss.

RESULTS AND DISCUSSION

The march of the soil moisture tension profile for a one year cycle is shown in Figure 1. Cropping systems which show fairly significant differences between them are presented in this figure. The following information of direct interest is afforded from these results.

1. Except under bare, clean-weeded conditions, and also under a weed fallow, there is a gradual depletion of moisture in the whole depth of the profile to tensions beyond wilting point through the dry *yala* months.

2. There exists a distinct difference in the rate of moisture consumption as well as the depth of moisture exploitation between different crops.

The evapotranspiration (i.e., the water lost by evaporation from the soil plus the water transpired by the crop) for seven of the cropping systems during the period October-January and also for the period April-May are given in Table 3.

Table III.—Evapotranspiration of cropping systems

Crop	*Period*	*Approx No. of days*	*Evapotranspiration in water*
Maize	Oct.–Jan.	120	16·4
Sorghum	,,	110	15·7
Groundnut	,,	110	15·9
Cotton	,,	120	16·1
Kurakkan	,,	118	18·8
Brachiaria	Nov.–Dec.	60	8·3
Brachiaria	Apr.–May	60	13·2
Alysicarpus	Nov.–Dec.	60	7·8
Alysicarpus	Apr.–May	60	12·9

The higher evapotranspiration recorded during the April-May period can be attributed to the higher solar radiation which is received during this time of the year in this region.

Penman (5) has devised a method of estimating the evaporation from a free water surface (Ew), from observations of sunshine hours, air temperature, humidity and wind velocity. His equation was applied to a five-year run of data from this research station and the resulting calculated values compared with measurements made from a 6 ft. square sunken cement tank. Close agreement was obtained for the months October to May, while less precise agreement was obtained for the months June to September. Penman (6) further studied the water loss from a grass turf in which the soil moisture supply is not limiting. Over the period of an entire year he found that the evapotranspiration from a grass cover (Et) was nearly 75 per cent. that from open water (Ew).

$$\text{i.e.} \quad \frac{Et}{Ew} = 0.75$$

In England this ratio varied from 0.8 in summer to 0.6 in winter and assumed different values for different soil moisture conditions.

Unlike a grass turf which has a complete leaf cover, an annual crop like maize or cotton initially starts with a bare soil and then goes through a period of steadily increasing leaf cover. Due to such circumstances, Penman's ratio requires further examination with respect to an annual crop.

The ideal rainfall distribution in *Maha* 1958-59 permitted reliable estimates of the seasonal trends of moisture consumption being made. The results for cotton and maize are discussed because these were sown with the first rains and germinated soon after. Monthly evapotranspiration values (Et) for cotton and maize are given in Table 4.

Table VI.—Monthly evapotranspiration for cotton and maize

Month	*Evapotranspiration in inches*	
	Cotton	*Maize*
October	3·53	3·53
November	3·40	3·42
December	4·06	4·15
January	5·09	5·31
February	6·46*	
March	—	
April	6·30	
May	5·66	

During the second half of February and during the whole of March, moisture conditions were limiting under cotton. * The value of 6.46 inches recorded for cotton in February was made up of 2.06 inches in the first week where moisture conditions were not limiting, and 4.4 inches in the next three weeks where moisture conditions were limiting.

The free water surface evaporation (Ew) for the period October 1958 to May 1959 was estimated by the Penman formula and the ratio Et/Ew calculated for each month in respect of cotton and maize. The results are shown in Table 5.

Table V.—Relationship between evapotranspiration [Et] and free water surface evaporation [Ew.]

Month	*Ew. in.*	*Et/Ew.*	
		Cotton	*Maize*
October	5·6	0·63	0·63
November	4·8	0·71	0·72
December	5·2	0·78	0·80
January	5·6	0·91	0·95
February	6·2	1·40	
March	7·5	—	
April	7·2	0·87	
May	6·9	0·82	

It is observed, that starting with a value of 0.63, the ratio Et/Ew steadily rises with increasing leaf cover of the crop until it reaches a peak value of 0.95 for maize. In the case of cotton, however, the ratio has exceeded a value of unity in the first week of February. Since soil moisture was limiting in the profile after this stage it was not possible to follow the trends beyond this point. Again, where soil moisture conditions were restored by April, the ratio has dropped to 0.87.

From the foregoing results it is observed that evapotranspiration for arable crops in this region could be reliably estimated from easily measurable meteorological factors which are employed in the Penman equation. Furthermore, a water consumption pattern for any crop can be constructed and matched against the rainfall characteristics, thereby permitting the best exploitation of any particular rainfall regime. These aspects will be discussed in a future publication.

ACKNOWLEDGMENT

Mr. W. S. Alles computed the Penman estimates and made careful measurements of run-off and local precipitation. Messrs. T. Sivanayagam and J. S. Selvaratnam laid out the experiment and carried out the field measurements. Messrs. T. B. Gamagedera and D. Kapugeekiyana also helped during some stages of this investigation.

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CONTROL OF INFECTIOUS DISEASES: II

By

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THE sheep industry in all parts of the world suffers economic losses from diseases in the flocks, one of the most important being blue tongue which was first recognized in southern Africa and more recently diagnosed in other parts of Africa, in some Near East countries, in some parts of the United States of America and in Portugal and Spain. The disease, caused by a virus with considerable powers of resistance, may spread rapidly within a given area, causing a mortality of about 10 per cent. in most outbreaks although the death rate may vary between 2 and 80 per cent. Much research work has been carried out on blue tongue, especially in South Africa, but there are still some important problems awaiting solution.

Field evidence indicates that the causal virus may be insect-transmitted and that sheep exposed to species of culicoides (midges), especially in low-lying, moist districts at night in the infected areas, contract the infection. Outbreaks occur only during the late summer months but it does not follow that sheep will become infected even when large numbers of midges may be present under conditions considered good for transmission. This may be because the midges do not carry the virus from one season to another and that the true reservoirs of the infection, at present unknown, are not present.

There is not yet exact information on the spread of the disease into non-infected areas or countries. It is known from experimental work that sheep which have recovered from the infection may continue to harbour the causal virus in a much reduced state of virulence for some weeks (120 days). Such recovered sheep may, therefore, continue to be a cause of residual infection.

Mutton Breeds more Susceptible

Blue tongue is essentially a disease of sheep, all breeds being susceptible, but mutton breeds more than Merinos. Variations of individual susceptibility occur within a breed. Cattle are also susceptible but to

a lesser degree. Affected cattle have been found in Israel and the infected European countries. It may be that the absence of the clinical disease in cattle in South Africa arises because of the exposure to the infection of the young animals when they are in a protected state from the passive immunity derived from their dams. Although cattle may show little or no clinical evidence of the infection, they can nevertheless, harbour the causal virus. There is evidence from experiments that the virus may be present for up to 70 days following artificial infection. It is also known that wild rodents may carry the infection.

Symptoms of the Disease

Blue tongue is characterised by a high temperature lasting from a few days to over a week, by reddening of the membranes of the mouth and nose, by discharge from the nose, by swelling of the lips, tongue and the space between the branches of the lower jaw, by peeling of the top layers of the skin of the lips and nostrils, by a general reddening of the skin, interfering with the nutrition of the wool and so causing breaks in the wool, sometimes by inflammation of some of the structures of the feet and by loss of bodily condition : affected lambs may show diarrhoea.

There seems to be little doubt that blue tongue is insect-transmitted but information on the reservoirs of the causal virus is still lacking. As it is impossible yet to eradicate the transmitting insects, prevention of the disease must consist in the annual mass vaccination of susceptible animals. From time to time different types of vaccine have been produced. The type now in general use is a vaccine consisting of four different strains of the virus whose virulence has been much reduced by passage through developing chick embryos : it is produced in a freeze-dried form and can, therefore, be kept for long periods under suitable conditions. This vaccine is giving generally satisfactory results : it is cheap, easily prepared, easily transported and safe to use except, perhaps, in ewes vaccinated for the first time during pregnancy, from a small number of which there is some evidence from America that abnormal lambs were born. Although, on the whole, this vaccine gives satisfactory results, a disadvantage is that, because so many strains of the virus are used in its preparation, a high immunity against all of them may not be established.

Swine Fever or Hog Cholera

In pigs, the disease which causes the greatest economic losses, generally speaking, is probably swine fever (hog cholera). It is found in most parts of the world where pigs are kept. The incidence varies from country to country : in some, the disease is endemic and, in spite of the efforts to control and eradicate the infection, repeated outbreaks occur, often associated with the movement of pigs. Some countries, which raise pigs on an extensive scale, have remained free from swine fever : this, to a large degree, is due to the prohibition of importation of pigs and pig products from other countries. It is well known that such importations, especially of pig products, have introduced the disease into countries which were free from the infection. The application of severe veterinary measures, following early recognition of the disease, have eradicated the infection in some of these countries.

Methods of combating the Disease

Undoubtedly, the most satisfactory results following the appearance of the disease in a country are obtained from a slaughter policy with restrictions of movement, the destruction of carcases of the slaughtered animals and careful disinfection of infected premises. By adopting such a system a country can, usually within a reasonable time, be freed from the infection. In countries in which the disease is endemic, however, a slaughter policy is usually impracticable, although the restriction of movement of pigs out of or into prescribed infected areas will prevent spread to other areas. The application of regulations for the cooking of all garbage (swill) has also a considerable value in preventing spread of the disease.

In countries in which swine fever is endemic, vaccination is usually practised, sometimes on an extensive scale. The simultaneous infection of the living causal virus and protective serum was used for many years and, although effective in controlling the disease, was not entirely satisfactory because some pigs became ill within a few days and breaks in the immunity were sometimes found after a few months. These occurrences were seen in spite of strict control of the potencies of the virus and serum. Extensive research in the United States of America has shown that these losses were due, probably, to the development of variants of the virus which were not affected by the serum.

Other types of immunising agents against swine fever have become available : there is the vaccine consisting of the virus exposed to the dye, crystal violet ; and the vaccine containing the virus attenuated

by passage through rabbits, used alone or simultaneously with protective serum. In general, these vaccines are giving favourable results: but unsatisfactory results, which are seldom found, are the subject of study at the present time.

African Swine Fever is Different

It is to be noted that the disease named African swine fever which, as its name implies, occurs in parts of Africa, is not the swine fever which occurs in other parts of the world. The causal agents are different and the protection against swine fever as carried out in many countries does not protect against the African disease. The African disease appeared recently in Portugal and was eradicated by the adoption of a slaughter policy.

All the diseases already discussed in these articles are, generally speaking, diseases of animals and not normally of human beings. There is some evidence that the viruses of foot-and-mouth disease and Newcastle disease have caused some localised human disease, usually very mild in character and quickly responding to treatment. There are, however, a number of infectious diseases of animals which also cause serious diseases in man. In this article, two are discussed.

Bovine Tuberculosis infects Humans

Bovine tuberculosis in cattle is responsible for considerable losses in production throughout the world where demands are made for high production in cattle and where husbandry methods favour the spread of the infective causal agent. In some of the less developed countries, and in regions where cattle are mostly on wide, free range, the incidence of the disease may be very small, but where milk production on intensive lines is carried out, bovine tuberculosis may exist to a marked extent. The freedom or comparative freedom of some regions from bovine tuberculosis is maintained to a considerable extent by the precautions taken to prevent its introduction. In considering bovine tuberculosis we must also remember that it is a disease of human beings, occurring mostly in children and adolescents. The causal agent is conveyed mostly by the consumption of products, especially milk, derived from tuberculous animals, as well as contact with infected livestock. Infected animals other than cattle may sometimes cause the disease in human beings. Monkeys, dogs, cats and pigs are all susceptible to bovine tuberculosis and may transmit the infection.

Infection means lower Milk Yield

In view of the damage done by the disease, much attention has been given to its eradication not only from herds of cattle but also from

whole countries. Some countries have been freed from the disease in the cattle : some will soon be free, while in others rapid progress is being made in the eradication of the infection. It has been shown, repeatedly, that higher production results from herds free from bovine tuberculosis, the lower production in infected herds being not only due to the direct effects, but also to the indirect effect of the disease in opening the way for other diseases.

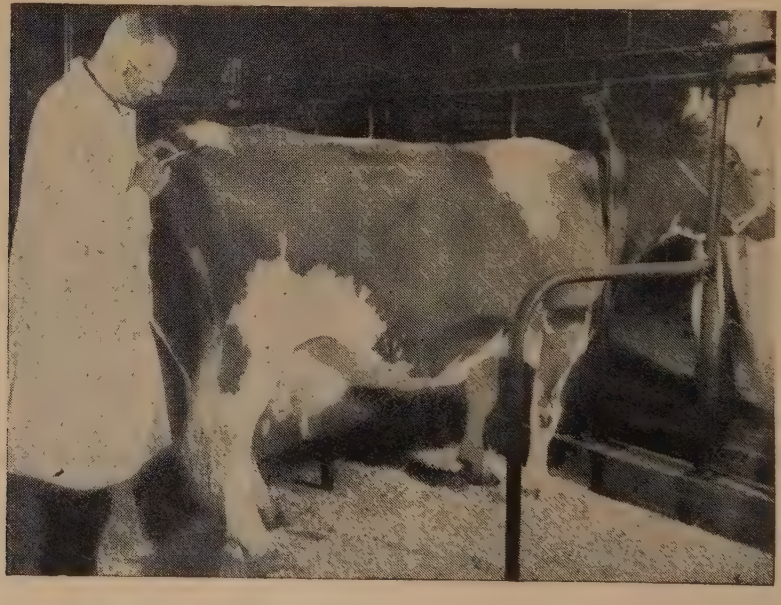
Some earlier attempts to control bovine tuberculosis in herds did not always prove entirely successful. The essentials in controlling and eradicating the disease are to discover the infected animals, to remove them at once from all contact with the other stock, to disinfect the premises occupied by them and to ensure that no further infection is introduced into the herd. While there may be a variety of ways in which the causal organism may enter a herd, the most important is the infected bovine, especially the animal which, so far as the eye can judge, is healthy. The disease may be present in some organ or tissue of the animal, even for long periods during which no outward signs are obvious. This is the dangerous animal because, quite suddenly, the infection in its quiescent form may become active and spread rapidly throughout the herd, even before any marked evidence of the disease is seen in the originally infected animal. Unfortunately, this animal is quite often a high producer and the owner fails to appreciate the harm which it may be doing. Such an animal also constitutes a danger to human beings.

Tuberculin Test is Safest Check

An acutely infected animal, with obvious signs of ill-health, may be diagnosed as suffering from bovine tuberculosis by the recognition of the causal agent in its bodily secretions or excretions, e.g., milk, sputum and faeces. Diagnosis by this method is not always satisfactory, because the causal micro-organisms may not regularly appear : it cannot be applied to the type of animal in which the lesion containing the active agents, but not excreting them, is temporarily sealed off. The only satisfactory diagnosis of bovine tuberculosis today is the application of the tuberculin test, especially by the intradermal method : there are few infected animals which fail to react to the test.

Tuberculin, produced from *M. tuberculosis,* has long been used in the diagnosis of tuberculosis in animals but the type of tuberculin, the methods of its application and the interpretation of the results have changed over the years. Most of the tuberculin in use today is a purified form which consists very largely of tuberculo-protein,

produced during the artificial culture of the organism. The site of the injection of tuberculin is also varied : in some countries, the neck is used while in others the injection is made into the fold of skin at the top of the tail—the caudal fold. A difficulty in the use of tuberculin is the sensitivity of animals in which infections other than true bovine tuberculosis exist : this also causes reactions to some types of tuberculin. Most of the tuberculins in use are derived from mammalian strains of *M. tuberculosis,* sometimes the true bovine strain, sometimes the human strain, sometimes a mixture of both strains. Tuberculins from these strains produce reactions not only in animals suffering from bovine tuberculosis but also in animals with other sensitivies caused, e.g., by the avian strain of *M. tuberculosis,* by the causal agent of Johne's disease and by the micro-organisms which give rise to so-called " skin tuberculosis ". The result is that, in the application of tuberculin of mammalian origin, an animal suffering from any of these infections may react positively. This difficulty can be overcome to a large extent by the use of two tuberculins simultaneously—one of mammalian origin and one of avian origin. Reactions to both tuberculins will be found in most animals with any of these infections, but the difference in the reactions as shown by their character and size assists in the determination of the presence or absence of bovine tuberculosis. The tuberculin test should be regarded as a herd test rather than as a test applied to an individual animal and the health history of a herd is of much value in the interpretation of the results of tuberculin tests.



Veterinarian injects tuberculin to commence a tuberculin test

Photo by courtesy F. A. O.

Herd Tests should be Repeated

In the eradication of bovine tuberculosis, the removal of animals reacting to tuberculin is essential, together with disinfection of the premises. It is also necessary to continue tuberculin testing at stated intervals in the remaining non-reacting animals in order to detect those in which the duration of the infection had not been sufficiently long to ensure their sensitivity at the former test. It may be necessary to repeat the tuberculin test in a herd a number of times until no reactors are found at two successive tests : it is only then that the herd may be accepted as free from bovine tuberculosis. Ideally, the disposal of reactors should be by slaughter and this is the system in some countries. It has been demonstrated, however, that, with the application of satisfactory precautions against the introduction of the infection, herds can be maintained free from the disease, although there are infected herds in the surrounding area.

Cattle Owners encouraged to Co-operate

The eradication of bovine tuberculosis from a country may begin by consideration of individual herds but, soon, the plan must concern areas until the whole country is covered. Cattle owners are usually encouraged to co-operate in any eradication scheme by the award of bonuses for milk from herds free from the disease or by an annual capitation grant : these are usually made available for a specified number of years.

Vaccination of cattle against bovine tuberculosis has been fully considered. While vaccines are used in human beings and experiments show that they also set up resistance to bovine tuberculosis in cattle, the many difficulties encountered in their application to cattle have resulted in a general veterinary opinion against their use.

Domestic animals, other than cattle, suffer from bovine tuberculosis. Swine, for example, are quite susceptible and in some countries, the disease in them is extensive. Swine also suffer from avian and human tuberculosis and, in the application of tuberculin tests, it is always necessary, as it is sometimes in cattle, to use tuberculin of mammalian and avian origins. The possibility of the transmission of bovine tuberculosis from swine has to be considered when eradicating the disease from an individual cattle herd, an area or a country.

May be confused with other Diseases

While, usually, the clinical picture of the disease is sufficient for recognising its presence, even the advanced disease may be confused with other conditions, especially internal parasitism. Microscopic examination of scrapings from the intestinal lesions may show the casual organism in infected animals, but the absence of the bacillus is not to be regarded as freedom from the infection, especially in animals in which the clinical symptoms have not yet developed to a marked extent. Other methods of testing for the presence of the disease have been the subject of study. The product, johnin, prepared by the cultivation of the causal organism in special liquid medium, is sometimes used for diagnosis, especially in the early stages of the disease. It is usually injected intradermally. Avian tuberculin is also sometimes used for diagnosis, injected intradermally, and causes a local reaction similar that produced by johnin. Although these products are useful in some cases, they are not entirely reliable. Serological tests have also been studied and are said to be particularly useful for diagnosis, especially in infected animals over a year old

Bearing in mind that large numbers of the bacilli are excreted in the faeces of infected animals and that young animals are particularly susceptible to the disease, methods of control should include the early detection and removal of infected animals and the early separation of the calf from its dam so that it may be reared out of contact with the infection.

Immunising Susceptible Animals

Some work has been carried out in immunising susceptible animals with vaccine containing the live virulent organisms incorporated in an excipient composed of mineral oil and finely ground limestone. It is injected into young animals which are negative to johnin and avian tuberculin tests. The injection produces a hard swelling which may persist for some years. There is evidence that vaccination is useful in heavily infected herds. Although the effects of a single injection of the vaccine may continue for some years, it is considered advisable to repeat vaccination every 15 months or even at shorter intervals. Treated animals become sensitive to tuberculin. This may cause some difficulty in the interpretation of results of the tuberculin test in treated herds. The use of the comparative tuberculin test, however, is of much assistance in determining the significance of the reactions.

From evidence collected in various countries, it is becoming apparent that Johne's disease is more prevalent throughout the world than was formerly appreciated. The need for the careful veterinary examination of all imported animals for the detection of this and other diseases must be stressed.

Three Strains of Brucellosis

Brucellosis is another highly contagious disease of cattle and other animals, transmissible to human beings. There are three more or less distinct strains of the causal agent—*Brucella abortus, Br. melitensis* and *Br. suis,* all of which may infect domestic animals on occasion although it is generally recognised that brucellosis is caused by *Br. abortus, Br. melitensis,* and *Br. suis* in cattle, in sheep and goats and in swine, respectively. Abortion is often a symptom of brucellosis, hence the commonly-used term "contagious abortion" in cattle. Many infected females, however, do not abort, especially when the disease has been present in a herd for some years and the infection may be present in male animals. The only way to diagnose the disease is by the recovery of the causal organism from the aborted calf, the foetal membranes or the discharges from the genital tract, or from the milk. The use of the agglutination test is also very valuable. In the absence of measures to control and eradicate *Br. abortus,* the disease may persist in the herd, resulting in an occasional abortion and irregular and difficult breeding. It may also happen, especially if susceptible breeding cattle are introduced into the herd, that the disease again becomes acute and a typical "abortion storm" results. The infection is easily conveyed to non-infected females by the discharges from the genital tract of infected animals, and even through their milk. While *Br. abortus* continues to be excreted from the infected genital tract until all discharges following abortion or calving have disappeared, the organism may still be found in the milk at irregular intervals over a long period.

The control and eradication of brucellosis in cattle may be accomplished in two ways. One is similar to the procedure for eradication of bovine tuberculosis, viz., the diagnosis and removal of infected animals, together with thorough disinfection and the prevention of further introduction of the disease. The infection has been eradicated from many herds by these measures; but, because of the ease with which the causal organism can be conveyed, considerable difficulties have been experienced in maintaining herds in a state of freedom.

Immunity lasts for some Years

The other method is the protection of animals by vaccination. This has been practised for many years, using vaccines prepared in different ways. It has been clearly shown that vaccines must consist of living *Br. abortus* so attenuated or reduced in virulence that their injection does not set up the disease. The most universally used vaccines at the present time consist of such organisms as the well-known Strain 19, discovered in the United States of America in a naturally-attenuated form. This organism has been shown, by carefully controlled experiments, to retain its state of attenuation after having been passed through many cows and thus its safety for use as a vaccine is ensured. The injection of a single dose of this vaccine into non-pregnant cattle sets up a relatively high state of immunity lasting for some years.

Vaccination at a young age renders animals resistant to the infection during the period of high susceptibility and lasts at least until a natural resistance develops with age. To obtain maximum results, the vaccine must be prepared by a process which is now well known throughout the world. Recent work has resulted in the preparation of this vaccine in a freeze-dried condition which means that, under satisfactory conditions of storage, it can be kept in a living and active condition over long periods. While the protection against infection is high, it may not always be absolute and "breaks" do sometimes occur. It is seldom, however, that an animal which has received potent vaccine at a suitable age, aborts even though some degree of infection may be present. The wide-scale use of the vaccine has been followed by a marked reduction in the incidence of brucellosis and this has led to the study of causes of abortion other than *Br. abortus*. A disadvantage of some importance with the use of the vaccine is the development of agglutinating substances in the blood of infected animals, so they may react to the agglutination test. This is of little consequence in many herds, for the object of the vaccination is to prevent the disease. On the other hand, in some cattle, particularly those for export, negative reactions to the agglutination test are required.

Age at Vaccination is Important

In considering such agglutination reactions, the age at which vaccine is injected is of importance ; the older the animal, the more do agglutination bodies tend to persist. The normal practise is to vaccinate calves, female and male, between the ages of four and eight months. Animals vaccinated at a younger age will probably

fail to be protected in later life because the mechanism for the production of protective antibodies will not have developed to the extent of being stimulated by the vaccine. Most of the heifers vaccinated between these ages will react negatively or only at "low titre" to the agglutination test by the time they reach breeding age. In non-vaccinated animals, a "low titre", however, may indicate the beginning of a natural infection. The significance of such a titre may be clarified if it is known that the animal was vaccinated at a certain age and that, just before vaccination, the blood agglutination test was negative.

Brucellosis of sheep and goats presents an important problem in some regions. It is commonly found in north African countries, some parts of east, west and south Africa, some European countries, especially in southern parts of the continent, some Near East countries, in South East Asia, in Mexico and in some States of the United States of America and in South American countries. In addition to the losses in animals, the disease also causes "undulent fever" in human beings. Infection occurs by handling infected animals and by consuming products, especially milk or unripened soft cheese, prepared from milk from infected goats and sheep. Within recent years, much research work has been carried out on brucellosis in sheep and goats. More is now known about the stages of infection at which *Br. molitensis* is excreted and about the persistence of the organism in the animal body.

New Vaccines being Produced

Considerable progress has been made in the preparation and evaluation of different vaccines for the prevention of the infection. Work in the laboratory and with small numbers of sheep and goats has shown that at least two vaccines are satisfactory immunising agents. We must now await the results of large-scale field trials of these vaccines before one or both can be recommended for general use. Much of the work on testing the value of the vaccines was done in Tunisia through technical assistance provided mainly by the Food and Agriculture Organization of the United Nations.

The characteristics of the three classical types of brucella, as shown by laboratory tests, have been recognised for a long time. There is now evidence that there exist brucella which do not correspond exactly to any of the three. "Intermediate types" have been found. One such has been recovered from a few milking cows in England: it shows some of the characteristics of *Br. abortus* and some of *Br. melitensis*, and was originally found in the milk. This finding led to the enactment of the Brucella Melitensis Order of 1940 which, among

other things, provides for the slaughter of cows in which this organism is found. In spite of its presence in the milk of infected cows, there is no evidence whatsoever that any infection of human beings, handling or drinking milk, has ever occurred.

Hares may be "Reservoirs" of Infection

Br. suis infection is found mainly in some European countries, in some Asian countries, often only in imported swine, and in parts of the Americas. Many countries are entirely free, doubtless either because no swine are imported or because very strict precautions are observed. In many of the infected countries the incidence of the infection is being reduced. A characteristic of the disease, at least in some European countries, is that outbreaks occur sporadically, without any apparent introduction of the infection into a swine breeding herd. In this connection, the infection has been found in hares and it is very likely that these animals act as reservoirs of the infection which gains entrance, periodically, to herds of swine.

Up to the present time, no satisfactory vaccine has been developed for the prevention of the disease. The only control method, admittedly not entirely satisfactory, is the diagnosis of the infected animals by the blood agglutination test and their removal from the herd and, preferably, slaughter and the careful disinfection of premises. Testing has to be continued until no further reactors are found. The boar must be included in the tests because of the part played by the male in the transmission and spread of the causal agent.

INFECTIOUS DISEASES OF ANIMALS: III

By

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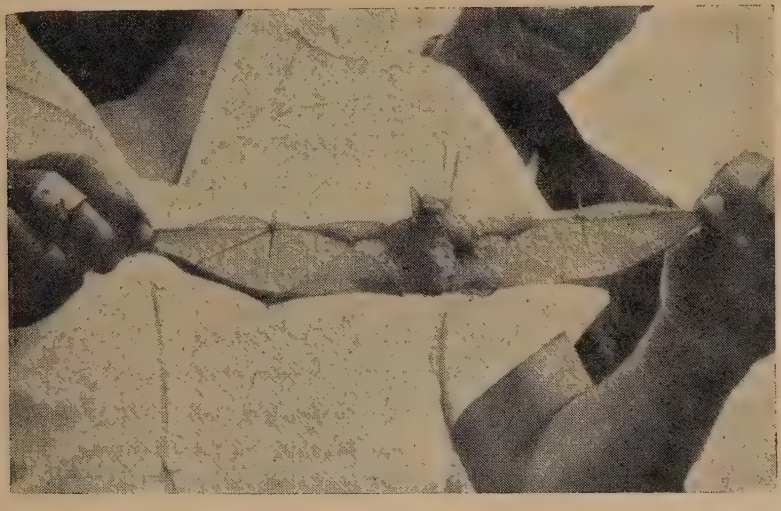
THERE are a few more important diseases which occur in both animals and human beings which are discussed in this article.

Rabies is widespread throughout many parts of the world : all types of animals are susceptible and may develop the disease when exposed to the causal virus. While, in some countries, it is seldom that rabies is found in any animals except dogs and cats, the susceptibility of domestic animals in general must not be forgotten, nor must we forget that wild animals, especially carnivores, may also develop the disease and may be spreaders of the infection. Again, attention is drawn to the part played in some parts of the world by blood-sucking bats in infecting domestic animals : it is also recorded that insectivorous and fruit-eating bats may, sometimes, also transmit the virus. Except in areas where blood-sucking bats are present or where wild carnivores have become infected, the infection is most commonly transmitted to



Close-up of a variety of Vampire Bat which transmits rabies to cattle

Photo by courtesy F. A. O.

animals and human beings by infected dogs and cats, whose saliva contains the causal virus. The recognition of the part played by infected dogs and cats in conveying the disease forms the basis of methods of control applied in many parts of the world.

Lengthy Period of Quarantine Essential

In countries normally free from the disease its introduction is guarded against by imposing strict quarantine measures, especially for all dogs and cats entering the country. Because there may be an interval of many months between the actual infection of an animal and the appearance of symptoms of the disease, a long quarantine period is essential. Criticism is sometimes made of the lengths of the quarantine period imposed by the authorities in some countries. Experience has shown, however, that they are necessary if the introduction of the disease is to be prevented ; in spite of all the opposition, the actions of the authorities must be supported in continuing to impose these lengthy quarantines, no matter how drastic they may appear to be.

It may not always be possible to diagnose rabies in an infected animal during life. The symptoms may vary considerably and it may be necessary to continue observation of a suspected animal for some days before definite clinical evidence of the disease is forthcoming. It is important, however, that all human beings bitten by dogs or cats in countries in which rabies is endemic should be placed under medical care, irrespective of whether or not it is proved that the animal in question is actually suffering from rabies. In dealing with rabies, intimate collaboration between veterinary and medical authorities is absolutely essential. The actual diagnosis of rabies is normally made by transmission of the causal virus contained in the central nervous system to small laboratory susceptible animals, e.g., mice or by the finding of typical changes in parts of the brain of infected animals by microscopic examination or by both methods.

New Types of Vaccine

Vaccination of animals is often carried out as a control measure. The treatment of human beings with vaccines following exposure to infection, e.g., bites by infected or suspected dogs and cats, has been practised for many years with excellent results. More recently, since the elaboration of new types of vaccine, especially those prepared from

strains of attenuated rabies virus cultivated in the developing chick embryo, vaccination campaigns for the prevention of the disease in animals are being carried out in several countries. There are now available vaccines which have been shown to afford protection for some years. Vaccination of the larger domestic animals is also practised in countries in which bat transmission of the infection is common.

Experience has shown that in campaigns in which vaccination of dogs is an essential part, it is necessary for success that the whole of the dog population of the area is dealt with : ownerless or stray dogs have to be destroyed and all other dogs registered and vaccinated. Unfortunately, the success hoped for has not been attained in all countries. The continued presence of infected wild animals, especially in neighbouring countries, constitutes a difficulty. It can readily be appreciated that international action may be necessary finally to eradicate rabies from a region.

Dead chick embryo from treated eggs is used for preparation of vaccine to immunize cattle against rabies.

Photo by Courtesy F. A. O.

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A youth holds his dog as inoculation is made at the Anti-rabies Centre in Mexico City
Photo by Courtesy F. A. O.

Leptospiral Infections in Animals and Humans

A group of organisms, designated leptospira, is responsible for the disease *leptospirosis* in domestic animals and human beings. Within recent years, our knowledge of these diseases in animals has advanced considerably although they have been recognised, for a long time, as causes of human disease, especially occurring where conditions of work expose the personnel to the infections.

Leptospiral infections may be found in all species of domestic animals and in all countries of the world, the incidence and the severity of the infections, both of which vary greatly, depending upon epidemiological and ecological conditions. Natural infections occur in cattle, sheep, goats, pigs, horses, donkeys, dogs and cats. Although there are many types of leptospira, it is seldom that more than one type is found in a species of animal ; a different type may, however, be found in the same type of animal in different parts of the world. It has also been observed that the same type of leptospira may be present in different species of animals.

Various Symptoms of the Disease

Leptospirae cause disease in which the symptoms and severity vary from an extremely mild condition to very severe attacks, resulting in deaths. Sometimes, it is necessary to employ laboratory tests on

blood to demonstrate that infection is actually present. Mild symptoms are often characteristic of the disease in pigs in which abortion may occur ; in horses, the infection may be localised in the eyes or may affect the central nervous system ; in cattle, the severity may vary from the occurrence of mild to severe symptoms with lowered milk yields, abortion, jaundice, high fever and even mastitis ; in dogs, the disease, especially following infection with some types, is often serious, with the occurrence of gastro-enteritis, jaundice and kidney troubles but, with other types, the disease is much milder in character.

Leptospirae are spread either by vectors, usually wild rodents, and by domestic animals which, although showing no symptoms of the disease, are carriers of the infective agents. The organisms, which are highly sensitive to heat and other adverse climatic conditions, can remain active in parts of the kidney and in the bladder for long periods and are excreted in varying numbers in the urine. Contamination of foodstuffs and water by infected urine is the usual source of the infection for domestic animals but actual contact with infected animals may also give rise to the disease.

There seems little doubt that methods of animal husbandry have an influence on the occurrence and spread of infection by leptospirae ; the more intensively animals are kept, the more likelihood is there of spread within groups.

Need for more Research Work

Control measures must vary according to circumstances and conditions. Wherever possible, infected animals should be diagnosed by the application of laboratory tests on their blood and a strict isolation of infected from non-infected animals should be practised. Measures should be adopted to ensure the exclusion of infection by wild rodents. Vaccines have proved useful in human medicine. There is still need for research work, especially with attenuated leptospirae, for the preparation of vaccines for wide use in animals so that immunity for at least one year can be provided.

Salmonellae infect Animals, Poultry and Humans

Members of the group of micro-organisms, termed *salmonellae,* are causes of diseases in animals and poultry. Some also infect human beings, the infecting bacteria being often found in animals and products of animal origin. There is also evidence that some of the infections in animals may be derived from infected human beings. The

group contains many members, but all of them are not disease producers : some are more virulent than others and some are responsible for disease in one species of animal more than in others. Some members of the group, at one time unknown in a country, have been introduced in imported products of animal origin, especially eggs.

In cattle, the most severe infections occur in calves, usually when about 10-15 days old and cause gastro-enteritis, often referred to as " white scour ". The disease is common in many parts of the world and can spread rapidly in a group of calves, especially if housed together under unsatisfactory hygienic conditions. In pigs, salmonella infections are often found concurrently with swine fever but they may also exist independently. Some of the salmonellae are also responsible for abortions, particularly in sheep and horses.

" Carriers " in the Animal World

As in human beings, " carriers " of the infection exist in the animal world. The cycle of infection in pullorum disease (bacillary white diarrhœa) is well recognised, in which breeding hens, recovered from the disease, may continue to harbour the causal organism and produce infected eggs, with high mortality of either the developing embryo or the young chicks soon after hatching. Cattle, which have been infected, even without much clinical evidence of the disease, may also continue to harbour the causal agents, i.e., they become " carriers ", and it is often from such animals that calves become infected. The introduction of such a " carrier " may establish the infection in a herd free from salmonellosis. It is not always easy to detect " carrier " animals. The recovery of salmonellae from the faeces is definite proof but, because excretion of the organisms is irregular, a single examination may give misleading results. Agglutination tests with serum from the blood of infected and "carrier " animals also give valuable information provided the specific salmonella involved is known. A combination of these two methods of diagnosis gives the most satisfactory results. The value of the agglutination test alone in detecting " carriers " of the salmonella causing pullorum diseases is, of course, recognised throughout the world.

Salmonellae may be conveyed mechanically from infected to healthy animals : flies, rodents or even wild birds may take part in this transmission. Infection may persist in faeces for long periods and, therefore, in considering control measures, careful and satisfactory disinfection of premises must be regarded as an essential part.

A further possible source of infection is animal foods and fertilisers prepared from inedible meat and offal from slaughter-houses, from contaminated fish and even from concentrates of vegetable origin. The possibility of such substances being infected with salmonellae requires their adequate sterilisation during preparation.

Humans may spread Infection

Attention must be drawn to the part played by human beings in the spread of salmonella infections. Human " carriers " working in abattoirs and engaged in any work necessitating the handling of meat and meat products may infect these substances.

In spite of the claims made for the successful treatment of acutely or even mildly affected animals, as with many other infectious diseases, the best results will always be obtained by the operation of preventive measures.

Before leaving the subject of diseases common to animals and human beings, stress must be laid on the importance of controlling the infections in animals, which play such a large part in their continuing presence in the human population.

Micro-Organisms associated with Mastitis

Inflammation of the udder in lactating animals, or *mastitis,* is one of the commonest diseases of cattle throughout the world. As milk production becomes intensified, the greater is the tendency to the occurrence of mastitis. The disease arises from the invasion of the delicate structures of the udder by micro-organisms which cause the development of the inflammatory processes resulting in acute or chronic mastitis. A large number of different micro-organisms is associated with mastitis and in controlling the disease it is highly important to know the types which are present in the udder. Different types of streptococci are common invaders and much work has been done on their classification and on their disease-producing qualities. Staphylococci cause mastitis in an acute form. Other organisms commonly associated with mastitis are *Corynebacterium pyogenes, Bacterium coli, Myobacterium tuberculosis, Clostridium welchii* and yeast-like organisms or fungi, while some workers think that there may also be a virus as an essential cause of some outbreaks.

In considering the control of mastitis we must always keep in mind that there are several predisposing causes which tend to lower the resistance of the udder tissue and open up the way for the introduction of the infecting agent. These include injuries, chilling of the

udder through exposure of the animal to sudden changes in temperature, rough handling of the udder, improper or imperfect milking either by hand or by machines ; feeding, too, may be related to the occurrence of the disease. Infectious agents are also conveyed from animal to animal by direct or indirect contact : this takes place by milkers' hands, contaminated teat cups, contaminated cloths for cleansing the udder and any other agent making such contacts. The part played by flies, especially in " dry " cows, has also to be considered.

The prevention of mastitis must centre round the avoidance of such contacts. Early recognition of infected animals is essential and for this purpose the use of the strip cup on each animal before milking is valuable. Some types of simple chemical tests can also be made. The recognition of the causal agents, however, can be done only in the laboratory where the necessary equipment and facilities are available. Much can be done in the milking sheds to prevent mastitis and its spread. Good milking hygiene and methods, as well as careful handling of the animals themselves, are essential and have been shown repeatedly to lower the incidence of the disease.

Treatment with Antibiotics

With the introduction of newer types of chemical agents and anti-bio tics, the treatment of mastitis has undergone marked changes. The use of antibiotics, injected into the udder through the teat canal is now the universal method of treating and even preventing most types of mastitis. It has to be recognised, however, that all the infecting micro-organisms are not equally responsive to the same antibiotic and that some are quite unresponsive to any of the antibiotics yet produced. It is, therefore, necessary to know which micro-organism is associated with mastitis in order that the agent to be used for treatment may be selected and that disappointment will not follow the treatment used.

Good Management reduces Mortality

Diseases among young animals vary considerably throughout the world ; mortality is high in regions where modern hygienic methods are not in everyday practice. Mortality among young animals can be reduced to a very low figure if good methods of management are introduced and precautions are taken to prevent obvious causes of ill-health. There are many causes : some are infectious agents which involve individuals or groups of animals, some are nutritional in origin,

some concern hereditary conditions transmitted by the dam or sire or both, some are essentially related to management. Salmonellosis in calves, which may spread rapidly was discussed in a previous article.

Infection of lambs and young sheep with the anaerobic group of micro-organism are examples of diseases found in different parts of the world, now being well controlled and prevented as the result of much research work. Our knowledge of anaerobic bacteria has been greatly increased by studies of some of the causes of mortality in lambs and young sheep. Most of the bacteria concerned produce toxins in the alimentary tract which, following absorption through the intestine, cause the animals' deaths. "*Lamb dysentery*" is an example of such a disease.

The bacterium responsible is *Clostridium welchii* which produces several toxins, some in excess of others, according to the conditions to which it is exposed. This multiplicity of toxins is reflected in the different diseases set up by infection with this micro-organism. It was known for a long time that it was an important cause of gas gangrene of toxic origin in the human subject, but it was only after diseases of sheep were studied that strains were found capable of producing several toxins, the individual toxins or a mixture of them causing the different sheep diseases. In lamb dysentery, one of the toxins is present in excess of the others. Infection takes place through the alimentary canal, the bacteria multiply in the stomach and intestine, where the toxins cause severe ulceration and absorption of the toxins takes place. Death is the usual sequence to the infection. In older lambs, excess of another toxin gives rise to the condition known as "pulpy kidney disease", so called from the changes observed in the kidneys soon after death.

Immunising against Bacteria and Toxins

These diseases can now be prevented to a large extent by immunisation against the infecting bacteria and their toxins. This may be carried out in three ways : antitoxins, produced mostly in horses, can be used on young susceptible lambs and sufficient immunity is conferred on them to carry them over the susceptible period; lambs may be immunised through their mothers; for the protection of older lambs against pulpy kidney disease, direct immunisation with vaccine may be carried out. Probably the most interesting result of the research work on these diseases is the transmission of immunity from the mother sheep to the lamb. Although a pregnant sheep may be highly immunised against these anaerobic toxins, her lamb is born quite free from any immunity and in a highly susceptible condition. However,

in immunised pregnant sheep, the protective substances accumulate in the udder to a high degree and, at its first suck, the lamb receives those protective substances which are absorbed through the intestine into the general system and thus immunity is acquired. These protective substances in the colostrum continue to be absorbed by the young lambs for several days, after which no further absorption takes place. This method of protecting young lambs is valuable in breeding flocks scattered over wide areas, where it may not be possible to handle newly-born lambs.

Diseases of the Respiratory Tract

Throughout the world there are many diseases of poultry of economic importance which interfere considerably with the development of the poultry industry. Some of them are now capable of being controlled and the results are reflected in better poultry production. Newcastle disease has been discussed in a previous article. The modern conditions under which poultry are maintained are conducive to the spread of infections and considerable damage may ensue in the absence of adequate measures of control. A difficult problem concerns the diseases of the respiratory tract, because some confusion exists on their differentiation, their causal agents and, therefore, the methods of their control. The tendency has been to apply the term "chronic respiratory disease" of poultry to almost any condition in which there was evidence of disturbance of the respiratory tract, including the air sacs. It has now been shown that several infectious agents may give rise to diseases of the upper and lower respiratory tract which, although specific, have very similar clinical symptoms and, further, that more than one infection may be present in the same fowl at the same time, when secondary complications have arisen. These various infections, however, can be differentiated by laboratory methods and so, the picture of poultry respiratory diseases is becoming clearer. The group includes infectious catarrh or coryza, infectious bronchitis, infectious laryngo-trachitis, sinusitis of turkeys, Newcastle disease, other mixed infections and true "chronic respiratory disease".

Need to identify Infecting Agent

For a long time the specific nature of chronic respiratory disease was doubted because of the failure to recognise the true causal agent and the association of pathogenic pleuro-pneumonia-like organisms (PPLO) with respiratory disease in general. Research and experiments have now shown clearly that virulent PPLO alone may

infect the respiratory tract and cause symptoms and lesions which may resemble those caused by other infectious agents. In some respects the clinical picture of some of these diseases may be very similar and laboratory examinations may be necessary to ascertain which disease is present. For some of the infections, curative and preventive treatment is available in the form of medicaments and vaccines. It is essential, however, to know the exact nature of the infecting agent, for a treatment which can be successfully applied to one may be of little value in others. In addition, emphasis must be given to the application of strict sanitary measures, including satisfactory disposal of dead fowls, and cleansing and disinfection of premises occupied by infected birds. Strict precautions should also be taken to prevent the introduction of any of the infections into healthy flocks by infected fowls or contaminated materials.

Treating Poultry infected with Fowl Pox

Fowl Pox, caused by a virus which produces symptoms and lesions affecting the respiratory tract and the skin, is still of economic importance in some regions and it is often necessary to adopt protective measures to prevent its occurrence and spread. Affections of the respiratory tract due to fowl pox are sometimes confused with other diseases and, in the absence of skin lesions, tests should be carried out to establish the true cause.

Satisfactory protection against fowl pox is obtained by the use of vaccine prepared from the causal virus. Formerly, it was necessary to " grow " the virus on the combs and parts of the skin of susceptible fowls and collect the lesions produced. Now the virus for vaccine production is usually cultivated in the developing chick embryo of fertile eggs. The virus of pigeon pox has also been used as a vaccine for protection against fowl pox: while considerable protection is afforded, the duration of immunity is comparatively short and its use has largely been replaced by vaccine containing fowl pox virus.

How to apply Vaccines

The application of the vaccine is carried out in different ways. It may be applied by scarifying a small area of the skin usually on a leg from which the feathers have been plucked and rubbing in a small quantity of the vaccine: it may also be applied by the " wing-stab " method, in which a sharp needle or somewhat similar instrument, dipped in the vaccine, is used to pierce the web of a wing, a quantity of the vaccine being left behind in the pierced skin. It is

always necessary to ascertain if the vaccine has "taken": a number of the treated fowls should, therefore, be examined on the third or fourth day after vaccination when the appearance of the treated skin should give positive indications by swelling of feather follicles of the treated area in the leg or by swelling of the skin surrounding the "stab" in the wing web. Very young chicks may be treated and successfully protected. Following the use of vaccine containing the live virus of fowl pox, an immunity of long duration results.

In this series of articles, only some of the infectious diseases of animals and poultry have been discussed. Many more are of considerable importance; space, however, will not permit their discussion.

Need for Early Diagnosis

In the diseases mentioned, little has been written on detailed symptoms nor on the methods and tests used for the diagnosis. This was done on purpose because an accurate diagnosis is essential before satisfactory methods of control can be applied. Veterinarians have the knowledge and experience to make the necessary diagnoses and to know when laboratory tests are required. The need to consult veterinarians on diseases of animals in their early stages cannot be over-emphasized. By so doing, there is every likelihood that the animal owner will benefit in many ways and the spread of a serious disease throughout a country may be prevented.

Animal owners can, of course, make important contributions to the prevention and control of diseases by practising good hygienic and management methods and by isolating at once any animal showing obvious signs of illness.

METEOROLOGICAL REPORT

Summary for July to September, 1959

ORDINARY monsoon weather prevailed over the Island during July, the rainfall being practically confined to the south-west quarter. Due to strengthening of the monsoon, comparatively heavy rainfall was experienced during two periods, viz. : 13th to 16th and 19th to 22nd. The greater monthly totals of rainfall (35 to 45 inches) occurred along the south-western slopes of the central hills. South-west coastal stations recorded totals between 5 and 10 inches. Outside the south-west quarter the monthly totals were mainly below 2 inches. Over 40 stations (in the north and the east) received no rain at all. Rainfall was mainly above normal in the south-west quarter but below normal elsewhere.

Normal monsoon conditions continued during August, most of the rainfall being confined to the south-west quarter. There were, however, two spells of thunder activity over the hill-country and in the north and east, one from the 8th to 16th and the other from the 27th to the end of the month. The bigger rainfall totals (ranging from 15 to 25 inches) occurred in the south-west quarter. Outside the south-west quarter the totals were mainly below 2 inches, except in the north-eastern region where they ranged from 2 to 10 inches. Over 30 stations (mostly in the north-west) received no rain at all. Rainfall during the month was above normal in the south-western low-country and mainly below normal elsewhere.

The chief feature of the weather during September also was the monsoon. The rainfall was again mainly confined to the south-western parts. The daily amounts were however chiefly light, there being only 3 days, 14th, 18th and 23rd, on which moderate rain was experienced to any appreciable extent. Monsoon weakened occasionally, resulting in evening thundershowers in the north or in the east. These were chiefly in evidence between the 15th and 23rd. The greater monthly totals (of the order of 20 to 30 inches) occurred in the south-western mid-country and the adjacent hill-country. Outside the south-west quarter the rainfall was mostly below 5 inches. Jaffna Peninsula received the least rain, almost all the stations there recording no rain. The rainfall was appreciably above normal in the south-western low and mid-country, while it was appreciably below normal in parts of the hill-country and Trincomalee and Jaffna Districts. Over the other parts of the Island the rainfall was about normal.

A. P. KANDASAMY,
Director.

Department of Meteorology,
Bullers Road,
Colombo 7, November 16, 1959.

JULY

	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of days
Anuradhapura ..	89·6	—1·3	75·8	0	67	88	0·48	—0·84	3
Badulla ..	86·1	—0·1	65·1	+0·8	63	89	0·97	—1·20	9
Batticaloa ..	93·7	+1·8	77·8	+0·9	59	78	0	—1·04	0
Colombo ..	84·8	+0·1	76·8	—0·1	80	86	7·34	+1·85	20
Diyatalawa ..	76·8	—1·1	63·4	+0·9	63	74	1·70	—0·26	9
Galle ..	83·1	+0·4	76·3	—0·3	82	88	5·38	—0·96	24
Hambantota ..	87·8	+0·5	77·4	+1·1	72	84	1·16	—0·85	3
Jaffna ..	85·2	—0·9	80 3	+1·0	78	80	0 02	—0·53	2
Kandy ..	80·2	—0·9	70 4	+0·6	76	88	12·41	+6·52	25
Kankesanturai ..	90·8	+0·9	80·3	+1·2	66	80	0·16	—0·38	2
Kurunegala ..	85·4	—0·9	74·9	—0·3	78	90	10·80	+6·92	23
M' Illuppallama ..	90·2	+0·6	74·8	—0·1	65	86	0·37	—1·08	6
Mannar ..	87·7	+0·4	80·3	+1·2	75	82	0	—0·35	1
Nuwara Eliya ..	64·6	—0·7	56·1	+1·2	82	83	11·38	+0·36	23
Puttalam ..	87·1	+0·9	79·0	+0·8	70	78	0·27	—0·72	5
Ratmalana ..	85·6	+0·9	77·4	+1·1	79	89	8·27	+2·81	22
Ratnapura ..	86·0	—0·6	73·6	—0·8	78	93	18·44	+5·67	27
Talawakele ..	67·8	—2·4	60·3	+0·8	87	94	15·11	+1·81	25
Trincomalee ..	93·7	+1·3	79·4	+1·4	57	74	0·43	—1·30	4

AUGUST

	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Offset	Number of days
Anuradhapura ..	93·5	+2·1	75·5	0	59	88	0	—1·62	0
Badulla ..	88·7	+2·7	64·6	+0·1	59	91	1·83	—1·37	9
Batticaloa ..	91·4	+1·0	77·5	+1·0	66	82	0·56	—1·39	1
Colombo ..	85·0	+0·1	76·4	—0·6	78	86	7·08	+3·05	19
Diyatalawa ..	78·1	+0·2	61·8	+0·1	64	81	1·76	—1·36	10
Galle ..	82·9	+0·3	76·5	— 0.2	80	84	11·10	+4·96	24
Hambantota ..	85·3	—1·6	76·5	+0·4	78	86	3·07	+1·63	8
Jaffna ..	86·6	+0·6	80·2	+0.9	79	82	0·15	—0·96	3
Kandy ..	82·2	0	69·1	—0·6	72	87	4·35	—0·39	15
Kankesanturai ..	91·5	+1·5	80·0	+1·0	66	82	0·06	—1·20	2
Kurunegala ..	87·0	+0·2	74·8	—0·1	73	88	3·09	—0·53	12
M' Illuppallama ..	92·8	+2·0	74·6	—0·6	57	86	0	—1·61	0
Mannar ..	87·8	+0·4	79·5	+0·8	75	85	0	—0·66	0
Nuwara Eliya ..	68·0	+1·9	54·4	0	76	85	4·32	—3·19	23
Puttalam ..	88·7	+2·1	78·6	+0·7	65	78	0·30	—0·35	4
Ratmalana ..	86·0	+0'8	76·9	—0·4	77	88	7·31	+3·83	22
Ratnapura ..	87·0	+0·2	73·3	—0·9	74	93	13·02	+1·63	23
Talawakele ..	70·8	—0·1	59·3	+0·1	76	91	7·37	—2·71	22
Trincomalee ..	94·0	+1·9	78·5	+1·2	58	76	2·24	—1·37	6

	SEPTEMBER								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps)	Total	Offset	Number of days
Anuradhapura ..	92·6	+0·8	75·3	+0·3	63	91	3·78	+0·02	8
Badulla ..	86·7	+1·0	65·5	+1·2	65	92	4·87	+0·38	11
Batticaloa ..	90·6	+0·9	77·6	+1·4	70	84	0·97	—1·42	6
Colombo ..	84 7	—0·7	76·0	—0·5	78	88	9·12	+2·28	23
Diyatalawa ..	77·2	—0·6	61·8	+0·9	68	84	2·71	—1·70	9
Galle ..	82·8	0	76·5	—0·2	82	86	12·63	+3·82	29
Hambantota ..	84·2	—2·3	76·2	+0·1	81	88	4.90	+2·14	15
Jaffna ..	86·5	+0·3	80·4	+1·1	80	85	0	—2·53	0
Kandy ..	82·0	—0·2	68·7	+1·2	74	90	5·50	—0·48	21
Kankesanturai ..	90·9	+1·1	80·3	+1·2	68	82	0·08	—2·94	1
Kurunegala ..	86·8	—0·9	74·6	+0·3	75	90	6·12	+0·57	19
M' Illuppallama ..	92·4	+1·2	74·5	—0·2	60	86	3·48	+0·38	8
Mannar ..	88·3	+0·6	79·9	+1·0	78	87	0·65	—0·59	4
Nuwara Eliya ..	66·9	+0·1	65·0	+1·7	80	85	6·48	—1·76	21
Puttalam ..	88·4	+1·4	78·4	+0·6	67	80	4·45	+2·87	10
Ratmalana ..	85·4	—0·3	76·5	+0·1	78	91	9·21	+2·37	25
Ratnapura ..	86·6	—0·6	73·3	—0·2	78	93	17·29	+3·07	26
Talawakele ..	71·0	—1·0	59·2	+0·9	85	94	7·69	—2·6	25
Trincomalee ..	93·8	+1·7	78·0	+0·9	61	78	3·18	—0·25	8

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